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NEW PROOFS OF THE KINETIC THEORY OF MATTER AND THE ATOMIC THEORY OF ELECTRICITY

By Professor ROBERT ANDREWS MILLIKAN, Ph.D., Sc.D.

UNIVERSITY OF CHICAGO

IT is my purpose herein to review the history of two of our most fundamental physical theories and to present some very simple and easily intelligible experiments which demonstrate the correctness of these theories, though they are by no means the only experiments which lead to the same goal.

If this statement seems too dogmatic and positive to be scientific let me say that I make it advisedly, for I wish vigorously to combat the point of view which I fear too many of those who are not engaged at first hand in scientific inquiry gain, both from the "revolutionary discoveries" which are continually being announced by the daily press, and also from the prominence which scientists themselves naturally give to the demolition of time-honored hypotheses in which they do not believe—the point of view that none of the theories of the scientists are after all any more than transient phenomena, that they are all just a part of the continual change and flux of things, that this generation discards wholesale all the hypotheses which were held adequate in the last and that the next generation will make equally short work of all the theories which hold sway to-day. In opposition to that point of view I wish to assert that there are some things, even in science, which we may safely say that we know, that there are some theories which we may be reasonably certain are going to endure—that in fact we may divide the theories of science into three categories, with broad and indefinite lines of division between them, it is true, but yet with real dividing areas, if not dividing lines.

In the first category may be placed the theories which we may say that we *know* are correct, using the word "know" not in the abstract

philosophical sense, but in the common every-day intelligible sense. As an illustration of theories which are in this category we may take the germ theory of disease, meaning by that the theory that some diseases at least are due to definite micro-organisms which invade the system. In 1850, before Lister's and Pasteur's discoveries this was a pure hypothesis. To-day it is an hypothesis which has been definitely proved to be correct, and which henceforth we may indeed extend and modify but which we need never expect to see abandoned.

Again, the hypothesis that the earth is a round ball, rotating daily on its axis, and swinging annually around the sun was a few hundred years ago a mere assertion which almost nobody believed; to-day it is an established doctrine which we may count upon to endure, though of course the earth may not always keep on doing what it is doing to-day.

In the second category are a large group of theories which are probably correct, but which may at any time be proved to be false; while in the third category are theories which are very uncertain, some of them being little more than "pipe dreams," the best perhaps which we can do in the present state of our ignorance, but the ignorance upon which they are based is after all abysmal. The nebular hypothesis was a fine illustration of one of these dreams. It was not a part of our knowledge, because, as Kelvin so well says, there is no knowledge until we have been able to apply exact quantitative tests to our hypotheses. In other words, there is no science without exact measurement. There may be many good guesses without it, many plausible explanations, but no real knowledge. Such exact quantitative tests the nebular hypothesis has never been able to call to its support.

Now the progress of science consists simply in the slow but continuous sweep of these two broad lines of division in the direction of the last category, that is, it consists in nothing else save the continual transfer of theories from category 3 over to 2 and from 2 over into 1, and it is my purpose herein to trace the most fascinating history of the gradual transfer of two of these theories, from the outermost edge of 3 across the two boundaries over into 1, where they now rest so securely established that it is not too much to say that there is as much likelihood that man will some day cease to believe in the rotation of the earth as that the kinetic theory of matter and the atomic theory of electricity will ever cease to be the corner stones of all physical science.

But first, just a word about these revolutionary discoveries which are continually being announced. Nine tenths of them are just as revolutionary as was the discovery of the seven-year-old boy who came home from school one day altogether disgusted, saying that for a week his teacher had been telling him that 3 and 4 made seven, and he had just got it well learned when she told him that 5 and 2 make seven. So it is with our discoveries in science. We do indeed discover new relations,

but for the most part the old ones remain. The atomic theory of matter, for example, was not even touched when radio-activity and the divisibility of the atom were brought to light, for nobody who had gone beyond the high school stage in science ever thought of asserting an indivisible atom, and that simply because we had no basis for asserting anything about the insides of the atom. We knew that there was a smallest thing which took part in chemical reactions, and we named that thing the atom, leaving its insides to the future, and the future proved itself abundantly able to take care of the trust.

Coming now to the first of our two theories, it is probably carrying coals to Newcastle to explain to an intelligent audience to-day what are the essential elements of the kinetic theory of matter, but I will at least carry enough of these coals to make a logical stepping-stone from the familiar to the unfamiliar.

The kinetic theory, then, when divorced from all non-essentials, is merely the assertion that everything in this world of ours is in a state of restless, ceaseless, seething motion, that all matter is composed of minute parts called molecules which are eternally pounding and jostling against one another. In gases these molecules are so far apart that the forces of attraction which exist between them are quite negligible and they dart hither and thither like gnats in a swarm, only with the stupendous speed of a mile a second (in the case of hydrogen) and richochette unceasingly against one another and the walls of the containing vessel, producing by this bombardment all the familiar phenomena of pneumatic tires and gaseous bodies generally. If you could magnify the air in an ordinary room just a thousand million times, that is, enough to make a good-sized marrowfat pea swell to the size of the earth, you would see objects about as big as a football—we will not say of what shape, because we do not know anything about it, but they would probably be of the same shape in a given gas—and if the motions would stop long enough to enable us to get a snap shot of the whole situation, you would see on the average one of these objects in a cubical space ten feet on a side. Then if you let them go again you would see each of these footballs shoot on the average through thirty such imaginary cubical rooms before it hit another. This distance we call the mean free path of a gas molecule.

In the liquid state the molecules are packed closely together by cohesive forces, yet they continually wriggle and squirm over and around one another, so that if you will be content this time with a 10 million-fold magnification, the liquid would look very much like a mass of wriggling squirming maggots—not a pretty picture perhaps, but a fairly accurate one I think.

In solids the molecules are for the most part locked up tightly in crystalline forms so that their motions are reduced to mere trembling,

unavailing protests against their hard imprisonment. If a biological analogy would make the picture more vivid you can imagine the cages of a menagerie arranged in squares or other regular figures, while the caged animals pace restlessly to and fro between their bars.

Increase in temperature means in all cases increase in the kinetic energy of agitation of the molecules, whatever state they may be in, and one of the fundamental assumptions of the kinetic theory, and one which we can now definitely prove, at least for gases, is that at a given temperature the average kinetic energy of agitation of a molecule is a universal constant, independent of whether the molecule is little or big. If the exact meaning of this statement is not clear, then imagine a lot of molecules of different weights from the big mercury unit down to the little hydrogen unit, one two-hundredth as heavy, led out in succession to a punching bag or to the striking machine at a county fair, and asked to register their strengths. They would, by virtue of a single impact, drive the index to just the same height, the lubberly mercury molecule being able to hit no harder, despite his size, than the tiny hydrogen molecule. This means of course that the hydrogen molecule must have a much larger speed, in fact a speed fourteen times as great in order to make up for his small avoirdupois. Such in brief is the kinetic hypothesis.

This hypothesis has had a long and checkered career in the course of which it has met with nearly all the vicissitudes which can befall a physical theory. Put forth in its most fundamental aspects by Leucippus and Democritus in the early dawn of Greek thought (about 440 B.C.) it was violently combated by the idealistic philosophers of the ancient world, especially by Plato and Aristotle, and remained altogether fruitless for two thousand years and more, in part, no doubt, because of the adverse influence of these great names. At the beginning of the modern awakening of the intellectual life it was resurrected by Descartes about 1630, and elaborated in considerable detail by Daniel Bernouilli in 1738. Nevertheless, up to the middle of the nineteenth century it remained to the world at large the rather fanciful and naïve speculation of a mere handful of philosophers. And although it is significant that this handful contains the names of the most prominent and productive of the makers of modern physics—Newton, Boyle, Rumford, Joule, Clausius, Maxwell, Kelvin, Boltzmann—nothing is more surprising to the student brought up in the atmosphere of the scientific thought of the present than the fact that the relatively complex and intricate phenomena of light and electricity had been built together into fairly consistent and satisfactory theories long before the much simpler phenomena of heat and molecular physics had begun to be correctly understood.

The first tremendous success of the kinetic hypothesis came about

the middle of the nineteenth century, when it gave birth to the principle of conservation of energy, a generalization which grew immediately and inevitably out of the mechanical theory of heat as it lay in the minds of Rumford, Joule and their co-workers. Between 1860 and 1890 the proofs of the kinetic hypothesis came in so rapidly through the brilliant work of such masters as Joule, Clausius, Maxwell, Kelvin and Boltzmann that the scientific world began to be convinced, and only here and there was found a man of standing among the scoffers. Then, about 1887, a reaction set in, and the school of energetics arose in Germany, which attempted to force the principle of conservation of energy to devour its own mother. The most spectacular of the onslaughts was made by Ostwald, who in 1895 wrote a widely circulated essay, entitled "The Demolition of Scientific Materialism," elsewhere printed under the title, "The Route of Modern Atomism." Led by such a bell-wether, the sheep began to jump back over the wall, and the results of that backward movement are still felt in the United States, particularly in high-school texts, despite the fact that to-day the opposition among scientific men to the kinetic hypothesis is absolutely gone, and even Ostwald has admitted his error. Indeed, so direct and so convincing is now the evidence that it is not too much to say that any one who wishes can now have immediate ocular demonstration of the perpetual dance of the molecules of matter.

But since we are here as much concerned with the atomic or granular theory of electricity as with the kinetic theory of matter, let us turn for a moment to consider the present status of our knowledge as to the nature of electricity. Unlike the kinetic theory of matter, the granular theory of electricity can boast of no great antiquity. Indeed, in its present form it is but ten or fifteen years old, and in no form is it more than one or two hundred years old. For there are no electrical theories of any kind which go back of our own Benjamin Franklin. It is true that the Greeks discovered that rubbed amber had the power of attracting to itself light objects placed in its neighborhood, but this is all until A.D. 1600, when Queen Elizabeth's surgeon, Gilbert, found that a glass rod and some twenty other bodies, when rubbed with silk, acted like the rubbed amber of the Greeks, and he consequently decided to describe the phenomenon by saying that the glass rod had become *electrified* (amberized, electron being the Greek word for amber) or had acquired a charge of *electricity*. In 1733, Dufay, a French physicist, further found that sealing wax, when rubbed with cat's fur, was also electrified, but that it differed from the electrified glass rod, in that it strongly attracted any electrified body which was repelled by the glass, while it repelled any electrified body which was attracted by the glass. About 1847, Benjamin Franklin adopted the following purely arbitrary convention, and said, We will consider that there are

two kinds of electrification, which we will distinguish by the terms positive and negative, and we will call any body positively electrified if it is repelled by a glass rod which has been rubbed with silk, and we will call any body negatively electrified if it is repelled by sealing wax which has been rubbed with cat's fur. These are to-day our definitions of positive and negative electrical charges. Notice that in setting them up we propose no theory whatever of electrification, but content ourselves simply with describing the phenomena. In the next place it was surmised by Franklin in 1750, and proved very accurately by Faraday in 1837, that when glass is positively electrified by rubbing it with silk, the silk itself takes up a negative charge of exactly the same amount as the positive charge received by the glass, and, in general, that positive and negative electrical charges always appear simultaneously and in exactly equal amounts. So far, still no theory! But in order to have a rational explanation of the phenomena so far considered, particularly this last one, Franklin now made the assumption that something which he chose to call the electrical fluid or "electrical fire" exists *in normal amount* as a constituent of all matter in the neutral, or unelectrified state, but that more than the normal amount in any body is manifested as a positive electrical charge, and less than the normal amount as a negative charge. Æpinus, an English admirer of Franklin's theory, pointed out that, in order to account for the repulsion of two negatively electrified bodies, it was necessary to assume that matter, when divorced from Franklin's electrical fluid, was self-repellent, *i. e.*, that it possessed properties quite different from those which are found in ordinary unelectrified matter. In order to leave poor old matter, whose independent existence was thus threatened, endowed with its familiar old properties, other physicists of the day preferred to assume that matter in a neutral state shows no electrical properties because it contains as constituents equal amounts of *two* fluids which they called positive and negative electricity, respectively, and that a positively charged body is one in which there is more positive than negative, and *vice versa*. The two theories are not, at bottom, very different, since Franklin's modified one-fluid theory required that matter, when divorced entirely from the electrical fluid, have exactly the same properties which the two-fluid theory ascribed to negative electricity, barring only the property of fluidity; so that the most important distinction between the theories was that the two-fluid theory assumed the existence of three distinct entities, named positive electricity, negative electricity and matter, while the one-fluid theory reduced these three entities to two which Franklin called matter and electricity, but which might perhaps as well have been called positive electricity and negative electricity, unelectrified matter being reduced to a mere combination of these two. Whether the electrical fluid (or fluids) was supposed to

be made up of particles, or to be indefinitely divisible, is not usually stated, though Franklin himself certainly believed in the existence of an electrical particle or atom, for he says: "The electrical matter consists of particles extremely subtle, since it can permeate common matter, even the densest, with such freedom and ease as not to receive any appreciable resistance." When Franklin wrote that, however, he could scarcely have dreamed that it would ever be possible to isolate and study by itself one of the ultimate particles of the electrical fluid. The atomic theory of electricity was to him a pure speculation.

The first bit of experimental evidence which appeared in its favor came in 1833, when Faraday found that the passage of a given quantity of electricity through a solution containing a compound of hydrogen, for example, would always cause the appearance at the negative terminal of the same amount of hydrogen gas, irrespective of the kind of hydrogen compound which had been dissolved, and irrespective also of the strength of the solution; that, further the quantity of electricity required to cause the appearance of one gram of hydrogen, would always deposit from a solution containing silver exactly 107.1 grams of silver. This meant, since the weight of the silver atom is exactly 107.1 times the weight of the hydrogen atom, that *the hydrogen atom and the silver atom are associated in the solution with exactly the same quantity of electricity.* When it was further found in this way that all atoms which are univalent in chemistry, that is, which combine with one atom of hydrogen, carry precisely the same quantity of electricity, and all atoms which are bi-valent carry twice this amount, and, in general, that valency, in chemistry, is always exactly proportional to the quantity of electricity carried by the atom in question, it was obvious that the atomic theory of electricity had been given very strong support.

But striking and significant as were these discoveries, they did not serve to establish the atomic hypothesis. Indeed, the attention which Faraday himself directed to the rôle played by the medium which surrounded a body carrying a charge, or the wire through which a charge was passing (an electric current) led to a point of view which was distinctly antagonistic to the atomic concept of electricity. This point of view was emphasized very strongly by the followers of Maxwell, notably by Oliver Lodge, who through his book on "Modern Views of Electricity" influenced very largely the points of view adopted by the text-books of the last two decades of the nineteenth century. This view was that an electric charge is nothing more than a "state of strain in the ether," and an electric current, instead of representing the passage of anything definite along the wire, corresponded merely to a continuous "slip" or "breakdown of a strain" in the medium within the wire, whatever these terms may mean. Now there can be no doubt that

when an electrical charge is placed upon a body, the medium about the body becomes the seat of new forces, and this may be described by saying that the medium about the body has been thrown into a state of strain. But it is one thing to say that the electrical charge on the body *produces* a state of strain in the surrounding medium, and quite another thing to say that the electrical charge *is nothing but* a state of strain in the surrounding medium, just as it is one thing to say that when a man stands on a bridge he produces a mechanical strain in the timbers of the bridge, and another thing to say that the man is nothing more than a mechanical strain in the bridge. The practical difference between the two points of view is that in the one case you look for other attributes of the man besides the ability to produce a strain in the bridge, and in the other case you do not look for other attributes. So the strain theory, although not irreconcilable with the atomic hypothesis, was actually antagonistic to it, because it led men to think of the strain as distributed continuously about the surface of the charged body, rather than as radiating from definite spots or centers peppered over the surface of the body. Between 1850 and 1900, then, the physicist was in the following anomalous and inconsistent position: When he was thinking of the passage of electricity through a solution, he pictured to himself definite specks or atoms of electricity as traveling through the solution, each atom of matter carrying an exact multiple of a definite elementary electrical atom; while, when he was thinking of the passage of a current through a metallic conductor, he gave up altogether the atomic hypothesis, and attempted to picture the phenomenon to himself as a continuous "slip" or "breakdown of a strain" in the material of the wire.

About 1900, however, a great stride forward was taken when the atomic hypothesis began to be applied to metallic conductors as well as to solutions, and electrical currents, even in wires, began to be looked upon as due to the transport through the wire of discrete units of electricity, now beginning to be called *electrons*, these units being either handed on from atom to atom or else being pushed along through the interstices between the atoms. This point of view, which was a return to Franklin's way of thinking, found its new justification in the fact that it was found possible in vacuum tubes of the X-ray type to obtain from all kinds of matter very minute electrically charged bodies of negative sign, which under all circumstances showed exactly the same behavior in electrical and magnetic fields and which had a mass which was computed to be but 1/1,760 the mass of the atom of hydrogen, the smallest known atom of matter. There was indeed no direct proof that the charges of these bodies were all the same, since no method had been found of examining them individually, nevertheless, it was pretty conclusively shown, as early as 1899, by Townsend of Ox-

ford, that the mean value of the charge carried by these electrons was the same as the charge carried by the hydrogen atom in electrolysis; and about the same time Sir J. J. Thomson found a way of making a rough determination of the absolute value of this mean charge. This method was improved in 1902 by H. A. Wilson, now of McGill University, and actually formed the starting point some five years later of the work out of which grew, by a series of natural steps, the experiments which are herewith presented and which have made it possible to capture and make accurate measurements upon one single isolated

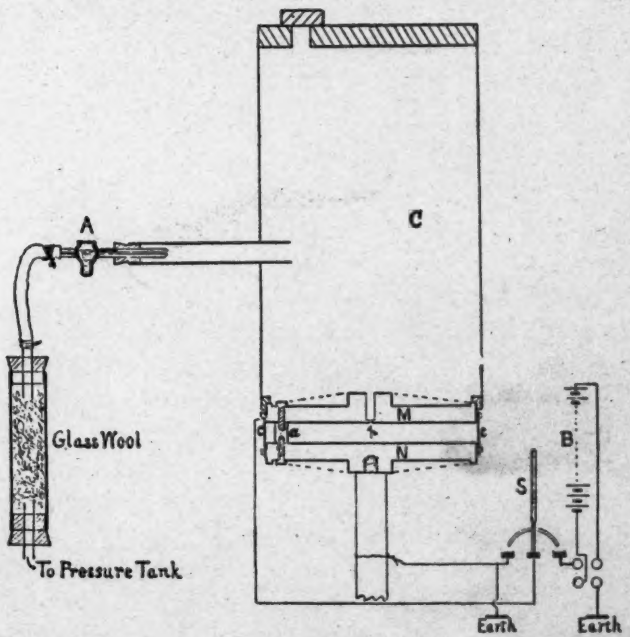


FIG. 1.

electron or any desired number of such electrons up to one hundred and fifty.

Imagine two circular plates M and N (Fig. 1) 22 centimeters (about 10 inches) in diameter and 16 millimeters ($\frac{3}{4}$ inch) apart which can be electrically charged, one positively and the other negatively, by making them the terminals of a ten-thousand-volt storage battery B. Suppose also that with the aid of a switch S the plates can be instantly discharged when desired so as to possess no electrical properties at all. Now when the plates are suddenly charged the air between them is found to remain perfectly quiet and free from convection currents of any kind—a result which shows that practically all of the air molecules between the plates are electrically neutral. But if now a beam of X-

rays is allowed to play upon the air between these two plates, it is found that some of these neutral air molecules are split up by the X-rays into electrically charged parts, which fly instantly, one part to plate *M* and the other part to plate *N*. This shows conclusively that the ordinary neutral molecules of the air possess electrical constituents, that is, that they contain equal quantities of positive and negative elec-

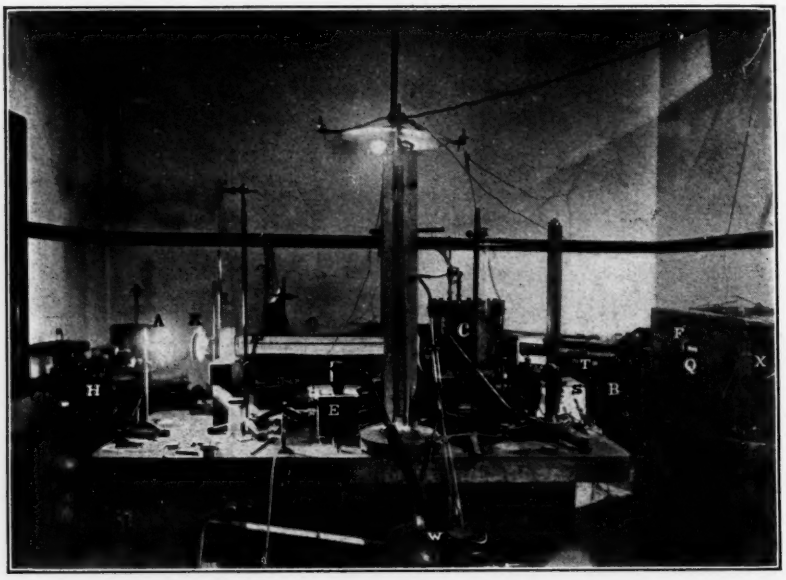


FIG. 2. *A*, arc light for illuminating droplet. *H*, chronograph for measuring speeds of droplet. *R*, lens for making the beam from the arc parallel or slightly convergent. *I*, shutter for intercepting altogether the light from the arc save when a reading of a transit of an "oil star" over a cross-hair was to be taken. This was used to insure entire stagnancy of the air between the plates *M* and *N* (Fig. 1). *E*, high potential static voltmeter from measuring *PD* produced by *B*. *P*, mercury pressure gauge or manometer for measuring the pressure of the air within *C*. *C*, air-tight brass chamber containing the plates *M* and *N* of Fig. 1. *W*, pressure pump for forcing a puff of air through the atomizer inside of *C* and above the plates *M* and *N*. The same pump is also used for exhausting the cylinder *C*. *T*, telescope for observing illuminated droplet. *S*, switch for throwing on or off the electric field between the plates. *B*, ten-thousand-volt storage battery. *T*, spot of light produced by the beam after passing through the two windows of the chamber *C*. *Q*, opening in lead box through which X-ray beam emerges on its way to chamber *C*, where it ionizes the gas between plates *M* and *N* of Fig. 1. *X*, X-ray bulb. *O*, cylindrical glass trough 80 cm. long filled with water for absorbing the heat rays from the arc.

tricity. Both ultra-violet light and the rays from radium possess, like the X-rays, the power of thus *ionizing* a gas, and even when no external ionizing agent whatever is at hand, it is found that out of the 27 billion billion molecules which are present in each cubic centimeter of ordinary air, from two to twenty split up per second into ions. As will presently be shown, this process of ionization consists in the detaching from a neutral molecule of an exceedingly minute fraction of its con-

stituent negative electricity—an electron—so that the residue of the molecule is probably just like the neutral molecules of the surrounding gas, save that it now carries a free or unbalanced positive charge corresponding to the negative charge of the electron which it has lost. The escaped electron probably soon attaches itself to a neutral molecule, so that shortly after the decomposition of a molecule, the gas is in the same condition as it was before the decomposition, save that two of its previously neutral molecules are now electrically charged, one positively and the other negatively. Whether this molecular decomposition which goes on continually in ordinary air is due to rays from traces of radio-active substances, which are present at all times in the air, or whether it is due to an occasional spontaneous explosion of a molecule, we can not as yet be absolutely certain, though the evidence is at present strongly in favor of the former hypothesis. But, however they may be formed, there can be no doubt of the presence of these ions in the atmosphere at all times, to the extent of from 1 to 15 per cubic millimeter, nor can there be any doubt that it is these atmospheric ions which are responsible for all the manifestations of atmospheric electricity which have been the object of man's awe and worship throughout all ages.

Now the problem which was set for this investigation was to catch individual ones of these atmospheric ions and to find what sort of charges they possess. A detective which could be set on the trail of a thing so small had evidently to be a distinctly undersized member of the force. It was in fact an oil-drop so minute as to be little more than visible through the most powerful microscope. In these experiments, however, no such high-power microscope was needed, for in a sufficiently powerful beam of light the oil droplet could be made to appear as a bright dot even to the naked eye in spite of its minuteness. The method of setting it at work was this. A spray of oil was blown from an ordinary commercial atomizer A into a dust-free chamber C, and one or more of the oil droplets was allowed to fall through a pin hole at p into the space between M and N. As it floated there, slowly falling under gravity, it was illuminated by a powerful beam from an arc light, which passed through diametrically opposite windows in the encircling ebonite strip c. It was viewed through a third window placed on the emergent side of the beam about fifteen degrees from its direction. A glance at the accompanying photograph, which shows a modification of the device, used for work at low pressures (see below), will make clear the arrangement of the different parts of the apparatus in the experiment now under consideration. The appearance of this drop of oil in the observer's short focus telescope through which it was viewed was that of a brilliant star on a black background. Be-

fore this star reached the lower plate the electrical field was thrown on and it straightway began to rise again toward the plate *M*. This was because in the atomizing process the droplet in general received a frictional charge; for, as is well known, strong frictional processes always produce electrification. If this charge was of the wrong sign to cause the drop to rise, rather than descend, when the 10,000-volt battery was thrown on, the signs of the charges on *M* and *N* were reversed. When the drop had been pulled up close to *M* the plates were discharged and the drop allowed to fall under gravity again until it was close to *N*. In this way, by alternately throwing on and off the electrical field, the oil drop detective was kept pacing its beat up and down between the plates in the hope that it would catch and hold some unwary ion which came within its reach. The first time the experiment was tried an ion was caught within a few minutes and the fact of the capture had been signalled to the observer by the change in the speed with which the drop moved up when the electrical field was on; for since the ion carried an electrical charge, its advent upon the drop changed the charge on the latter and therefore changed the speed with which it was pulled up toward *M*. If the sign of *M* was positive, then the drop itself, in order to be pulled up by the field, must have had a negative charge and in that case the capture of a positive ion reduced this negative charge and therefore reduced the speed in the field, while the capture of a negative ion increased the negative charge and hence increased the speed in the field. From the sign, then, and the magnitude of this change in speed, taken in connection with the constant speed under gravity, the sign and the exact value of the charge carried by the captured ion could be easily determined.

A drop would often be kept traveling back and forth in the manner described for four or five hours at a time, in the course of which it would change its charge twenty or thirty times because of the capture of ions and the value of each of these different charges would be computed. The beauty and precision of the measurements and the certainty with which the atomic theory of electricity follows from the results obtained can best be appreciated by inserting in full the record of an experiment made upon a particular drop. The column headed *G* gives the successive times which the droplet required to fall between two fixed cross-hairs in the observing telescope whose distance apart corresponded in this case to an actual distance of fall of .5222 centimeter. It will be seen that these numbers are all the same within the limits of error of a stop watch measurement. The column marked *F* gives the successive times which the droplet required to rise under the influence of the electrical field produced by applying in this case 5,051 volts of potential difference to the plates *M* and *N*. It will be seen that after the second trip up, the time changed from 12.4 to 21.8, indicating, since in

this case the drop was positive, that a negative ion had been caught from the air. The next time recorded under *F*, namely, 34.8, indicates that another negative ion has been caught. The next time, 84.5, indicates the capture of still another negative ion. This charge was held for two trips, when the speed changed back again to 34.6, showing that a positive ion had now been caught which carried precisely the same charge as the negative ion which before caused the inverse change in time, *i. e.*, that from 34.8 to 84.5.

G	*F*
13.6	12.5
13.8	12.4
13.4	21.8
13.4	34.8
13.6	84.5
13.6	85.5
13.7	34.6
13.5	34.8
13.5	16.0
13.8	34.8
13.7	34.6
13.8	21.9
13.6	
13.5	
13.4	
13.8	
13.4	
Mean 13.595	

Now all of the successive values of the charge carried by the drop throughout the experiment can be easily computed from the constant speed under gravity and the successive values of the speed in the electric field. To find the *absolute* values of these charges it is indeed necessary to know the weight of the drop, and the determination of this weight may involve an error of a fraction of a per cent. at most, but since this weight remains constant throughout the experiment the *relative* values of the successive charges can be found with absolute certainty and with great precision without any knowledge of this weight. They are in fact simply proportional to the successive values assumed by the sum of the two speeds, viz., that under gravity and that in the field.[1]

[1] For in the case of bodies moving slowly and uniformly through a resisting medium any two forces produce velocities which are proportional to the forces. The downward force due to gravity is here mg and the upward force due to the field is Fe, in which F denotes the strength of the field and e the charge on the drop. Hence, if v_1 is the downward velocity due to gravity and v_2 the upward velocity due to the excess of the upward pull of the field over the downward pull of gravity, we have

$$\frac{v_1}{v_2} = \frac{mg}{Fe - mg} \quad \text{or} \quad e = \frac{mg}{Fv_1}(v_1 + v_2).$$

Similarly the charge carried by any captured ion is proportional to the change produced in this sum by the capture. Now the change in this sum produced by the capture of the ion which caused the time in column *F* to change from 34.8 to 84.5 was, as any one who wishes can verify, .00891 cm. per sec. and the successive values of this sum arranged in order of magnitude were .04456, .05347, .06232, .07106, .08038. If now electricity is atomic in structure all the different charges appearing in this experiment, those on the ions and those on the drop, should be exact multiples of the elementary unit of charge, which means that all of the numbers above given should be exact multiples of something. Dividing the above five numbers by 5, 6, 7, 8 and 9, respectively, gives .008912, .008911, .008903, .008883 and 008931, which are all seen to be within one fifth of one per cent. of the value of the *change* in the sum of speeds produced by the capture of the ion which caused the numbers in the column *F* to change from 34.8 to 84.5. *Hence the charge carried by this ion was itself the elementary unit out of which all of the other charges which appeared in the experiment were built up.* The results on another drop which was observed through a much longer time, namely, about four and a half hours, are given in the following table:

n	4.917 × *n*	Observed Charge	*n*	4.917 × *n*	Observed Charge
1	4.917	——	10	49.17	49.41
2	9.834	——	11	54.09	53.91
3	14.75	——	12	59.00	59.12
4	19.66	19.66	13	63.92	63.68
5	24.59	24.60	14	68.84	68.65
6	29.50	29.62	15	73.75	——
7	34.42	34.47	16	78.67	78.34
8	39.34	39.38	17	83.59	83.22
9	44.25	44.42	18	88.51	——

In this table 4.917 is merely a number obtained, precisely as above, from computing the change in the "sum of speeds" produced by the capture of a particular ion, while the column headed "observed charge" gives the successive values of the sum of speeds. It will be seen that during the experiment this drop carried all possible multiples of the elementary charge between 4 and 18, save only 15. *No more exact or more consistent multiple relationship is found in the data which chemists have amassed on the combining powers of the elements, and on which the atomic theory of matter rests, than is found in the above numbers.*

Nearly a thousand different drops have been examined in the manner indicated, some of them being of oil, a non-conductor, some of glycerine, a semi-conductor, some of mercury, a good conductor, and some of other substances, and in every case, without a single exception, the initial charge placed upon the drop by the frictional process, and all of the dozen or more charges which have resulted from the capture by the drop of a larger or smaller number of ions, have been found to be exact mul-

tiples of the smallest charge caught from the air. Some of these drops have started with no charge at all, and one, two, three, four, five and six elementary charges or electrons have been picked up. Others have started with seven or eight units, others with twenty, others with fifty, others with a hundred, others with a hundred and fifty elementary units and have picked up in each case half a dozen elementary charges on either side of the starting point, so that in all oil drops containing every possible number of electrons between one and 150 have been observed and the number of electrons which each drop carried has been accurately counted. It is not found possible to count with certainty the number of electrons in a charge containing more than 200 of them, for the simple reason that the method of measurement used fails to detect the difference between 200 and 201. But it is quite inconceivable that large charges such as are dealt with in the commercial applications of electricity can be built up in an essentially different way from that in which the small charges whose electrons we are able to count are found to be. Furthermore, since it has been definitely proved that an electrical current is nothing but the motion of an electrical charge over or through a conductor, it is evident that the experiments under consideration furnish not only the most direct and convincing of evidence that all electrical charges are built up out of these very units or electrons which we have been dealing with as individuals in these experiments, but that all electrical currents consist merely in the transport of these electrons through the conducting bodies.

The next important question which the above method of experimenting seemed calculated to throw additional light upon is, "What does the ionization of a gas molecule consist in?" Since it is now practically certain that a molecule of air, that is a molecule of nitrogen or oxygen, contains at least a hundred electrons, and possibly very many more, the act of ionization might consist in the knocking out from a single one of these molecules of a large number of electrons, or it might consist in the complete shattering of an atom by some sort of explosive process; or, on the other hand, it might consist merely in the detaching of a single electron from a neutral molecule, thus leaving the molecule essentially the same sort of thing that it was before the ionization took place, save that it has acquired an amount of electricity of the opposite sign equal to that of the charge detached. Some little light can be thrown on this question by studying the observations already presented. In these observations, however, all the changes of charge took place when the drop was falling under gravity, that is, when the electrical field was off, and this for the reason that the chance which a drop has of capturing an ion when the field is off is enormously greater than its chance of catching one when the field is on, since, in the latter case, the electrically charged fragments of an atom, formed by the ionization of a

neutral molecule, are thrown instantly to the plates *M* and *N*, their speeds in the field here used being something like five or ten thousand centimeters per second; but, when the field is off, these ions remain in the air between the plates, and, sooner or later, as their number increases, one or more of them comes into contact with a drop and sticks to it. If we look now at the changes which occurred in the experiment recorded, we see that the first change in the time in the field, namely, that from 12.45 to 21.85, represented the advent upon the drop of 2 unit charges, since the 16-second time which is found later in the table was skipped in this catch. All the other changes in the table, save one, namely, that from 34.8 to 16.0, represented the advent of single charges, and this one represents again the advent of a double charge since the 21.9 second speed was here skipped. This indicates that there are probably no ions which have a very large number of units of excess of one kind of electricity upon them, but it gives us no information as to whether the act of ionization consists in the detachment of only one elementary electrical charge from a neutral molecule, or of two or three; for, so long as the changes are occurring when the field is off, it is impossible to distinguish between the capture of a single ion carrying two or three units of charge, and the successive capture of two or three ions each carrying the unit charge.

It was necessary, therefore, to catch the ions at the very instant of their formation, or better, *to catch a molecule in the very act of splitting up into ions.* Accordingly, the experiment was modified as follows. By suitably adjusting the *PD* between the plates *M* and *N*, it was found possible to hold a minute positively charged drop suspended, like Mohammed's coffin, as long as desired between heaven and earth, that is, in this case between *M* and *N*, the downward pull of gravity being exactly neutral-

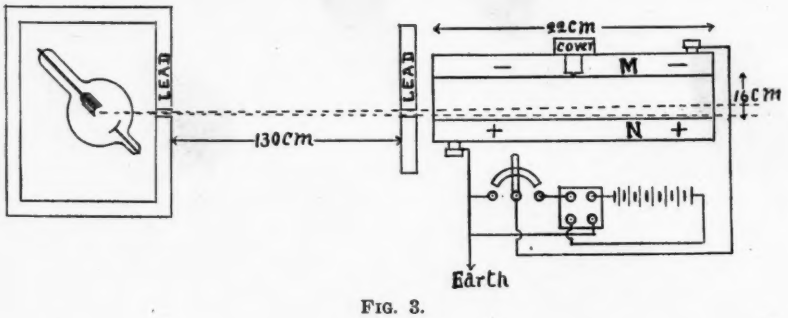


FIG. 3.

ized by the upward pull of the field. Having obtained a drop in this position, there was produced beneath it a sheet of X-ray ionization in the manner shown in Fig. 3, so that when the X-ray bulb was excited, the drop was in a veritable shower of the charged positive residues of the molecules broken up by the X-rays. Now, if two or more electrons were

knocked out of a molecule at once, the residue of the molecule would possess a corresponding number of unit charges, and if this residue were caught by the oil drop, the latter should be seen to jump forward at the instant of capture because of the destruction of the equilibrium between gravity and the electric field; and, furthermore, from the speed which it assumed, as measured by the time which it took to move over a given number of the divisions in the scale of the eye-piece of the observing telescope, the size of the charge of the captured ions could be determined. The experiment was found to be as interesting and as exciting as trout fishing. The star under observation would often stand perfectly still for five, ten, fifteen or even sixty seconds and then suddenly start forward with a speed which was big or little according to the size of the catch and the size of the drop. When we were using large drops, it was found that two or three adjacent molecules were in occasional instances ionized at once, and therefore two or three separate ions were thrown simultaneously upon the drop, but when the drops were very small, we observed in the course of three months about 500 different catches without finding a single one which corresponded with certainty to the advent of an ion carrying more than one elementary electrical charge, and not more than three or four out of the five hundred which were in any way uncertain. This seems to prove conclusively that *the act of ionization by all the types of X-rays and gamma and beta rays of radium which we have been able to try consists in the detachment from a neutral molecule of one single electron.*

So far we have considered merely the proof afforded by the present experiments of the atomic theory of electricity. I have not attempted to tell "what electricity is," but have been content with demonstrating, that whatever it is it always appears as an exact multiple of a definite electrical unit. If you ask me to tell you what it is, I should answer by asking you first to tell me what matter is, and if you responded that matter is that out of which this world and the planets and the stars of this universe are made; that it is something which exists in the form of about 100 different units, or atoms, of relative weights between 1 and 240, which atoms unite together in different ways to form molecules; that the average diameter of one of these atoms is two hundred-millionths of a centimeter, then I should answer, Very well, if you are content with that sort of a definition of matter, I will define electricity for you in a similar way and say that electricity is something which is still more fundamental than your atoms of matter since it is a constituent of every one of these hundred different types of atoms which you have been describing. It is something too, which like matter is built up out of definite units, but it is unlike matter, in that all of these units are exactly alike so far as we are able to determine, save, however, that a marked difference is found between the positive and negative units. For

while the two possess the same charge, the inertia or mass which, so far as we know, is inseparably associated with a positive unit is that of a hydrogen atom, while that inseparably associated with the negative unit is 1/1,760th as much. The negative units, furthermore, or electrons, are so small in volume and are separated from one another within the atom by so large spaces, that one of them can shoot through hundreds and thousands of atoms without hitting anything or doing anything whatever to these atoms. Its diameter is about one one-hundred-thousandth of that of the atom. It is the smallest thing we know anything about so far—probably the smallest thing in existence. Such an enumeration of properties is as near to a definition of electricity as we can come now or are ever likely to be able to come. For, since electricity is the most fundamental thing thus far known to us, it is obviously incapable of definition in terms of anything more fundamental. Its elementary unit, according to the best determination which we have yet been able to make, is 4.80 times 10^{-10} so called electrostatic units, a quantity so small that the electrical charge produced by a single stroke of a cat's back contains billions of them, while the number which courses each second through the filament of a common 16 candle power incandescent lamp is about a billion billion. The electron is thought by many reputable scientists of the present day to be the primordial thing out of which all matter is built up, so that from this point of view the different atoms of ordinary matter are merely different groupings of these fundamental electrical units.

Turning next to the kinetic theory of matter, what have the present experiments to do with it? There are three different ways in which they bring to it powerful support. When these experiments were begun it was anticipated that positively charged ions would be caught by negatively charged oil drops and negatively charged ions by positively charged oil drops, but it had not been predicted that positively charged drops would catch positive ions and negatively charged drops negative ions; for since electrical charges of like sign always repel each other, it might be thought that positive drops would push away positive ions and negative drops negative ions. As a matter of fact, however, positive ions were found to be caught by positive drops about as readily as the negative ions and *vice versa*. The above table shows several catches of this kind. Whence, then, do positive ions obtain the energy which enables them to push themselves up to the surface of a positive drop against the electrical repulsion existing between the two? This energy could not have been obtained from the field, since the capture of the ions occurred when the field was not on. It could not have been obtained from any explosive process which frees the electron from the molecule at the instant of ionization, since in this case, too, ions would have been caught as well, or nearly as well, when the field was on as when

it was off. *Here, then, is an absolutely direct proof that the ion must be endowed with a kinetic energy of agitation which is sufficient to push it up to the surface of the drop against the electrostatic repulsion of the charge already existing on the drop,* and when we remember that an ion is nothing but a molecule containing an unneutralized electrical charge, it will be clear that we have here direct proof that the molecules of the gas are endowed with motion.

Furthermore, it is easy to obtain the energy of this motion, for, if we load up the drop with more and more positive charges, the push which it will exert on positive ions within the gas must become greater and greater, and hence the frequency with which positive ions will be captured from the gas should become less and less. Now this is exactly what was observed to be the case, and, indeed, in one instance, a relatively heavily charged drop was watched for four hours, *during which time it succeeded in picking up but one single ion of its own sign* while the field was off, although it was continually picking up ions of the opposite sign. Its charge was during all this time maintained at about the same value by forcing ions of its own kind upon it *when the field was on.* We had then here a charged drop which exerted just enough repulsion upon the positive ions of the gas to overcome their kinetic energy of agitation when they shot toward it. By knowing the size of the drop and the charge which it carried, it was easy to compute from these two quantities just what this kinetic energy of agitation had to be in this case. It came out within a few per cent. of the value of the kinetic energy of agitation of the molecules as given by the kinetic theory.

But even this evidence is not sufficiently direct to convince a skeptic untrained to follow the computation, simple though it be. Hence a proof was sought which involved no knowledge whatever of either mathematical or physical theory. Fortunately the trail had already been blazed and nothing had to be done but to clear out some of the remaining underbrush which obscured it. It had been discovered as early as 1827 by an English botanist, Brown, that microscopic particles in a liquid keep up incessantly a very minute trembling motion and this phenomenon remained altogether unexplained for more than half a century. At last in 1888 it was suggested by Gouy in France that this trembling motion was probably due to the fact that when a particle is sufficiently small the molecular bombardment which it receives from the molecules surrounding it is not at a given instant exactly the same on opposite sides, and in consequence the particle is pushed first in one direction and then in another by these unbalanced molecular forces. In 1908, Perrin, in Paris, with the aid of a formula deduced by Einstein of Bern, had brought forward quite convincing evidence that this explanation was correct, but Perrin's observations had all been made upon

minute particles suspended in liquids, and liquids are very much less suited to any convincing and accurate test of the kinetic hypothesis than are gases. Apparently the very great advantages of observing minute suspended particles in a gas at very low pressures, where the motions ought to be enormously increased, had not been appreciated, or, at least, had not been utilized, perhaps because the means had not before been at hand for keeping such particles in suspension. Accordingly, the plates *M* and *N*, shown in Fig. 1, with the atomizer attached, were placed inside a large brass cylinder, which could be sealed air tight and exhausted if desired. This apparatus is shown in the photograph on p. 426. When the air was at atmospheric pressure, the smallest particles produced by the aspirator showed clearly the incessant wiggling motions which are called, after their discoverer in liquids, the "Brownian movements." But, when the pressure was reduced to seven or eight millimeters of mercury (about 1/100 of an atmosphere), these motions had increased so enormously in violence that it was difficult to follow the smallest particles as they dashed hither and thither like wrigglers in a water barrel. The reason that reducing the pressure brings out the motion so much more clearly is obviously this: When the oil drop is surrounded by a dense swarm of bombarding molecules, it is like a football in a mêlée of densely packed players who are kicking it on all sides at once, but are unable to send it any appreciable distances. But when it gets out into the open, where the players are scarce, it begins its spectacular flights. Precisely so with the oil drops, and no football game was ever more spectacular or more fascinating than the behavior of one of these oil drops at low pressures. The fact that the motions increase in violence the rarer the gas becomes and the smaller the particles are taken (size being indicated by the speed with which a given particle settles under gravity) is obviously just what ought to happen. There can not then be the slightest doubt that what these oil drops are doing, namely, dancing about violently in all sorts of directions, is precisely what the molecules themselves are doing in a much more excited way for it would be absurd to suppose that the increased speed and the increased distance of the motions as size and mass diminish do not go on after the particles cease to be visible and shrink to molecular dimensions. From the standpoint of a molecule which is darting hither and thither with the speed of a rifle bullet, our dancing oil drops must look like snails crawling about with languorous slowness. But to us they have served their purpose, for they have enabled our minds to see the invisible molecular world doing in a large way just exactly what the oil drops are doing in their small way. They have proved the kinetic theory of matter even to the man on the streets.

But in order literally to pile Ossa upon Pelion in support of this hypothesis, let us next turn to a rigorously quantitative demonstration,

for, while seeing the oil drops dance may satisfy the average man, it will not satisfy the scientist, for he is never content until he has two parallel columns headed, respectively, "calculated" and "observed" values. How shall we set about obtaining such parallel columns? The way was blazed by Einstein in 1905. He showed that if a body like one of our minute oil drops is dancing about in a resisting medium subjected to no forces but those arising from its own energy of agitation, that is, from the bombardment of the surrounding molecules, the mean distance which it will drift in a given time, say ten seconds, from its position at the beginning of this time, can be computed in terms of three factors: (1) its energy of agitation, (2) a resistance factor of the medium, and (3) the length of the time interval through which the drift is observed.[2] But this same quantity can also be easily and directly *observed* in our experiment by simply balancing the force of gravity upon the drop by the force of an electrical field in the manner already described, and then noting over how large a distance *on the average* it wiggles in a given time by virtue of its energy of agitation. In the actual experiments we took, in the case of each drop, the mean of several hundred observations on the distance moved in ten seconds in a vertical direction over a set of horizontal scale divisions placed in the eye-piece of the observing telescope; for Einstein's theory was developed in such a way that the movements to right and left did not need to be considered. The computed and the observed values of this average displacement were in every case in so perfect agreement as to satisfy the most skeptical of scientists that the kinetic theory can successfully meet a rigorous and exacting kind of quantitative test.

But in order to show how free from uncertainties of any sort are the results of this comparison it will be necessary to say just a word more about the theory, for the question is at once raised "how, in computing the theoretical value of the average displacement of the drop, do you obtain the first two of the factors in terms of which this displacement is given, namely, the kinetic energy of agitation of the drop and the resistance factor of the medium?" We obtain a partial answer to this question when we remember that one of the fundamental assumptions of the kinetic theory is that the energy of agitation of a molecule is determined by temperature alone, and is independent of

[2] Einstein's actual equation is $D^2 = 4/3 \cdot E/K \cdot t$, in which D^2 is a quantity obtained by squaring each individual displacement and then taking the mean of these squares, E is the mean kinetic energy of agitation of the drop, K is a resistance factor depending upon both the medium and the drop, and t is the length of the time interval used. If the *average* displacement D is used instead of the average square of the displacements D^2 the correct form of the equation is

$$D = \sqrt{\frac{8}{3\pi}\frac{E}{K}t}.$$

whether the molecule is large or small. Hence, the energy of agitation of our oil drop ought to be exactly the same as that of one of the molecules of the gas which surrounds it. But this is the quantity which we have just determined experimentally, and which, furthermore, can be computed with great precision from the kinetic theory.[3] Hence, we may consider that this quantity is known. The second factor, however, is not known with certainty, except under conditions which may or may not be fulfilled in any experimental work, and herein lies the uncertainty in all preceding attempts like those of Perrin to subject the kinetic theory of Brownian movements to any rigorous experimental test. Fortunately for the present work, however, *this factor does not need to be known* at all. For obviously the resistance which the medium offers to the motion at a given speed of this particular drop though it must be the same whether it is an electrical force, a gravitational force, or a force arising from molecular bombardments which is causing the motion. Consequently all that was necessary for us to do in order to eliminate this resistance factor entirely was first to observe the successive displacements of the *balanced* drop as indicated above and then to destroy the balance and measure how fast the drop moved on the average, both under gravity and under an electrical field of known strength, in precisely the way we had done when we were determining the successive values of the charge carried by the oil drops. From the results of the two experiments we could then eliminate the resistance factor and obtain the average displacement in terms of quantities every one of which was measurable with the greatest precision.[4] Indeed the experimental error in measuring the aver-

[3] The kinetic theory equation is $E = 3/2 \cdot RT/N$ in which E is the mean energy of molecular agitation, R an accurately known gas constant, T the absolute temperature, and N the number of molecules in 2 grams of hydrogen. Although N is not accurately known save through experiments of this sort, it fortunately does not need to be known, as will be shown in the next footnote, for the quantitative test here sought. When the above value of E is substituted in the equation of the last footnote it becomes

$$D = \sqrt{\frac{4}{\pi}\frac{RT}{NK}t}.$$

[4] When the drop is moving down through the medium under the force of gravity, mg, alone, its average velocity v_1 is given by $mg = Kv_1$. The substitution of this value of mg/v_1 in the equation of the footnote on page — gives $e = K/F \cdot (v_1 + v_2)$ and the elimination of K between this equation and that given in the preceding footnote gives

$$D = \sqrt{\frac{4}{\pi}\frac{RT(v_1 + v_2)t}{F(Ne)}}.$$

Since D was of course different for different drops instead of making the comparison between the observed and calculated values of D it was thought preferable to make the comparison in every case between the value of Ne obtained

age displacement was far greater than the uncertainty in any of the factors in terms of which this displacement was computed. *Nevertheless, the final result obtained from the average of 1,735 displacement observations on nine different drops was within less than one fourth of one per cent. of the computed value, and the probable error in this result was but six tenths of one per cent.*

All of these computations relating to the Brownian movements were carried out most skilfully by Dr. Harvey Fletcher. It should be added, too, that in only a portion of the experiments was the observed value of the displacement obtained in precisely the manner indicated above, for it was found that greater accuracy could be obtained in the measurement of this displacement by a slight modification of the method. To make this modification applicable, however, a considerable amount of new and important theoretical work had to be done. This work was most ably and successfully carried out by Dr. Fletcher, and can be found in the August number of the *Physical Review*.

It would seem as though the evidence for the kinetic theory were so overwhelming as to convince every type of skeptic except the one whose mental attitude is that of the farmer who had never seen any save farm-yard animals until he went one day to the circus and stood for some moments looking in amazement at the dromedary; then turning away, he exclaimed, "By gosh, there ain't no such animal." That type of disbeliever I am at a loss to know how to convert.

In conclusion it may be pointed out that not only has it now become possible to prove the correctness of the kinetic theory of matter and the granular theory of electricity, but that, through the results of experiments like the above on the elementary electrical charge, we are now able to determine the exact weight of every atom and every molecule of every known kind of matter, the exact number of molecules in any weight of any substance, the exact value of the kinetic energy of agitation of a molecule, the mean diameter of any kind of molecule, and quite a series of other important physical magnitudes. The first three of these quantities can be found with precisely the degree of accuracy attained in the measurement of the elementary electrical charge, and this is an accuracy of about *one part in a thousand*. Not that I am ready to assert that the value which has been given above possesses that degree of certainty; but rather that we now have a method which is capable of yielding such precision, and the rest is merely a matter of

from this equation and these experiments and the value of Ne obtained from experiments on electrolysis; for Ne is merely the amount of electricity required to separate by electrolysis one gram-equivalent of any substance from a solution. The value of $\sqrt{Ne}$ obtained from the most accurate experiments on the electrolysis of silver is 1.702×10^7 electrostatic units. The mean value of $\sqrt{Ne}$ obtained from 1,735 displacement measurements upon nine different drops was $1{,}698 \times 10^7$ electrostatic units.

time and of careful work. We are at present engaged not only in checking this value under new sets of conditions, but in redetermining all of the quantities which enter into it. Assuming it as the basis of our computation there are in a cubic centimeter of gas under normal conditions 2.70×10^{19} molecules and the weight of a hydrogen atom is 1.735×10^{-24} grams. These numbers can be made more significant to the ordinary reader with the aid of an illustration. If a million men were to be set counting as fast as they could count, say at the rate of 200 a minute, they could count out the number of molecules in a cubic centimeter in just 252 thousand years if none of them ever stopped to eat, sleep, or die.

"But," says some one, "What of it any way? Does the triumph or defeat of the kinetic theory of matter or the atomic theory of electricity have anything to do with the *practical* problems of the modern world? Is anybody going to be better fed or better clothed because of it?" the answer is, "Within the past seventy-five years—the merest drop in the bucket of recorded time—the conditions of human life on this earth have been completely revolutionized, and that solely because, for the first time in history, man has become interested in considerable numbers, rather than, as heretofore in isolated instances, in patiently and persistently seeking merely to uncover nature's 'useless' secrets, and then, when the inner workings have been laid bare, has in many cases seen a way to put his brain inside the machine and drive it where he would. Every increase then in man's knowledge of the way in which nature works must in the long run increase by just so much man's ability to control nature and to turn her hidden forces to his own account."

UNIVERSITY EDUCATION IN CHINA

By THOMAS T. READ

SAN FRANCISCO, CAL.; FORMERLY PROFESSOR OF METALLURGY, IMPERIAL PEI YANG UNIVERSITY, TIENTSIN, CHINA

ANY account of modern university education in China must necessarily be prefaced by a brief outline of that ancient system of education which has exerted perhaps the most powerful single influence of any that have made themselves felt in the development of a civilization more ancient than any other that now survives. For the forces which are shaping the new educational ideals have roots that strike down into the old, therefore, some consideration must be devoted to the past if we hope to regard the present with clear eyes.

The year 1902 makes an epoch in the educational history of China, for it was signalized by the promulgation of edicts by the Emperor Kuang Hsü which did away with the ancient educational system and created a modern one in its stead. It need scarcely be added that so radical a change was preceded by a period of preparation and followed by a period of adjustment; this latter indeed can scarcely be said to have yet been outgrown. For it is no light task to recast an educational system so vast that it applied to the students of a nation of 350 million people, and so ancient that the academy which stood at its head has an unbroken history of twelve hundred years.

The ancient educational system of China has been described at length by many well-known writers and it will not be profitable to do more here than draw attention to some of its salient features and briefly allude to some popular misconceptions regarding it. Lucidity requires brevity of statement, and the latter precludes the conveying of an accurate idea of any phase of oriental life, which is infinitely varied and complex. I shall attempt to adhere to brevity, in the hope that thereby the reader may not be led too far astray. The old official system was not one of education, but of examination; a modern analogue is perhaps seen in the University of the State of New York. The representatives of the official system were not concerned with the means by which the student obtained his education, their duty being to keep the examination standards so high that the number of successful candidates should not be excessive. Successful candidates were eligible for appointment to official positions, which were limited in number. So, emphasis was laid upon the wrong phase, the making difficult of successful achievement, rather than the easy attainment of an adequate education.

Elementary education was imparted to children in their homes by tutors, or in small private schools, seldom exceeding twenty pupils. There were no schools for girls, but a certain number were taught by members of their own family. In China, as in America, much of the teacher's reward had to be obtained from the dignity and honor of his occupation, for the fees generally paid were small. There were no requirements to be met by the teacher; any one might engage in the occupation, neither was any curriculum nor books prescribed, except by tradition. For the first four or five years the child devoted himself to memorizing the classics, learning to recognize and pronounce the characters, but without knowing their meaning, much as if a modern child were required to commit the Iliad to memory without understanding one word of it. Toward the end of the period the child was given a translation of what he had learned, and taught a little writing and easy composition. In this connection I can scarcely do better than quote Père L. Richard:

> **The whole system labored under serious disadvantages, resulted in a considerable waste of time and had little educational value. The memory and imitative powers were marvelously developed, but the mind was not stored with valuable ideas nor trained in precision and accuracy, and there was an utter lack of originality.**

Secondary education comprised the study of Chinese literature, and history, the writing of literary essays and stilted verses. When ready the student might go up for examination. The first examination was held yearly in the prefectural cities (which may be roughly likened to county-seats) throughout the empire. The successful candidates received the degree of *hsiu-ts'ai,* and were privileged to attend the second examination held every third year in the provincial capitals. The severity of the competition can be judged from the fact that where from twelve to twenty thousand were examined, only about one hundred would pass. These received the degree of *chü-jên,* and were allowed to attend the examination at Peking, also held once in three years. Here, out of 6,000 candidates about 300 would pass and receive the degree of *chin-shih.* These degrees are often compared to the B.A., M.A. and Ph.D., but the comparison is totally misleading. The Chinese idea of them is shown by the fact that in the modern system the first degree is given grammar-school graduates, the second to high school graduates, and the third upon the completion of professional courses, such as law or engineering. The criteria were skill in the composition of literary essays, in which adherence to prescribed form was desired rather than originality, and purely mechanical proficiency in writing the characters. It will be seen at once that this was a system of elimination rather than of education, and it is not remarkable that the educational results thus obtained were comparatively barren. From this cause, and others too

complex to be discussed here, the intellectual life of China remained upon nearly a dead level, while the western world was advancing from medieval ignorance to twentieth-century enlightenment.

The beginning of modern education in China must be ascribed to missionary influence. As soon as the first missionaries had learned something of the Chinese language and civilization they set about teaching those whom they were able to reach something of western knowledge as a necessary preliminary to evangelical work. Thus missionary bodies were sending out educational pseudopodia throughout the nation which could not be without effect in its mental life. The more astute statesmen engaged for their children foreign tutors, some of whom were later prominent in influencing progress, and many young men were sent abroad to study.

But perhaps the most powerful factor in encouraging the introduction of modern education into China was the Chino-Japanese war of 1895. The lesson of that conflict was a plain one, and the meaning was brought home to his countrymen by Chang Chih-tung in his "*Chuen Hioh Pien*," which, translated into English as "China's Only Hope," is widely known. This epoch-making treatise received the sanction of the emperor and was ordered to be published and circulated throughout the empire. In 1898 the emperor, influenced by Kang Yu-Wei and others, among other radical reforms, ordered the establishment of modern schools in all unused temples. The Empress Dowager's *coup d'état* followed, and soon after the volcanic upheaval of 1900. The lesson of this, added to that of 1895, was painful but convincing. In 1902 the present educational system was established by imperial decree, and in 1905 the old system was similarly abolished.

Chang Chih-tung had strongly urged the advisability of making use of all that the Japanese had done to adapt western culture to oriental needs, and it naturally followed that the scheme for a national system of education was largely modeled after that of Japan, of which a full discussion by H. Foster Bain may be found in an earlier number of this journal. The system now in force may be briefly summarized as follows:

Primary schools (a five-year course) are to be opened everywhere throughout the empire. Higher primary schools (four-year course) are to be established in the district towns the graduates of these receive the *hsiu-ts'ai* degree. Middle schools (five-year course) are to be established in prefectural cities. High schools (often called provincial colleges) (a three-year course) are to be opened in every provincial capital, their graduates receive the degree of *Chü-jên*. A university at Peking completes this scheme, awarding the degree of *Chin-shih*. Advanced technical schools are apparently not to be included in the university, but are separately established. The courses of study to be followed are largely modeled upon Japanese practise, Chang Chih-tung having been

a member of the board which drew up the plan of a national system of education. For example, the course of study prescribed for students of mining is exactly that of the University of Kyoto as given on p. 251 of this journal for March.

The plan of organization for the Imperial University at Peking, as translated by F. Hawkes Pott, is as follows:

1. Faculty of Classics; 10 courses, among which are: (*a*) The Book of Changes; (*b*) The Book of Annals; (*c*) The Book of Poetry; (*d*) Spring and Autumn Annals; (*e*) Rites; (*f*) Confucian Analects, and the Books of Mencius, with commentaries; (*g*) Philosophy.

2. Faculty of Jurisprudence; 2 courses: (*a*) Administration; (*b*) Legislation.

3. Faculty of Arts; 9 courses: (*a*) History of China; (*b*) Universal history; (*c*) General geography; (*d*) Geography of China; (*e*) Geography of England; (*f*) Geography of France; (*g*) Geography of Germany; (*h*) Geography of Russia; (*i*) Geography of Japan.

4. Faculty of Medicine; 2 courses: (*a*) Medicine; (*b*) Pharmacy.

5. Faculty of Science; 6 courses: (*a*) Mathematics; (*b*) Astronomy; (*c*) Physics; (*d*) Chemistry; (*e*) Natural history; (*f*) Geology.

6. Faculty of Agronomy; 4 courses: (*a*) Agriculture; (*b*) Chemistry relating to agriculture; (*c*) Forestry; (*d*) Veterinary science.

7. Faculty of Engineering; 6 courses: (*a*) Civil engineering; (*b*) Mechanical engineering; (*c*) Electrical engineering; (*d*) Architecture; (*e*) Industrial chemistry; (*f*) Mining engineering and metallurgy.

8. Faculty of Commerce; 3 courses: (*a*) Banking and insurance; (*b*) Commerce and transportation; (*c*) Customs.

All these courses are expected to be covered in 3 years, except medicine and law, for which 4 years is allowed. It is allowable for provinces to establish universities, which must conform to this scheme. At the Pei-Yang University, of Chili Province, the courses 2(*a*), 7(*a*), and 7(*f*) have been organized and in other provinces more or less effective universities have been founded. The University at Peking is still in course of development and I do not know the exact stage reached at the date of writing. It is evident that Faculty 1 and Faculty 3 are sops thrown to the former literati of the old school. The best work under this scheme has been done by the Pei-Yang University, referred to again later, which has for some years had an adequate staff of American professors.

So much for the plan; what of its fulfillment? From the viewpoint of the difficulty of the task it is remarkable that so much has already been done, in the face of so many unfavorable circumstances as have developed. The progress in Chihli province is shown by the following figures, taken from the report of the provincial board of education for 1907. If later reports were at hand they would undoubtedly show a

TOTAL ATTENDANCE IN CHIHLI PROVINCE

Year	Number of Students	Increase
1902	2,000	——
1903	8,000	6,000
1904	46,254	38,254
1905	88,000	41,746
1906	135,416	47,416
1907	173,352	37,936

SCHOOLS IN CHIHLI PROVINCE, 1907

Schools	Number of Schools	Number of Teachers	Number of Students
University	1	13	98
Provincial college	1	9	205
Industrial and special (middle grade) schools	13	118	1,612
Industrial and special (lower grade) schools	17	40	446
Upper normal schools	2	46	395
Lower normal schools	98	165	3,448
Middle schools	32	157	2,125
Upper primary schools	220	521	10,599
Lower primary schools	8,675	8,969	148,397
Half-day (or night) classes	121	133	2,971
Girls' schools	121	163	2,625

continuous growth. In all fairness it should be noted that, compared with Chihli, the other provinces would make but a sorry showing, though those which have within their borders large treaty ports, such as Hongkong, Shanghai, Hankow, Ningpo, Amoy and Foochow, have also done well, and the remote province of Ssu-ch'uan, especially so, considering its remote geographical position. It will be perceived that support of the new system is almost proportional to acquaintance with the foreigner, and in developing this support the educational work of the missionaries, both protestant and catholic, has had a preponderating influence, though the material rewards derived from the foreigners' superior knowledge are not unperceived and unappreciated.

A false impression may easily be obtained from figures such as these, by inferring that the results accomplished in these schools are comparable to those of similar foreign schools, which is far from true as yet. This results from a number of causes. Perhaps the chief of these is that the control of the national and provincial educational boards has remained largely in the hands of the officials of the old system, who naturally are rather ineffective in putting the new in force. This has already begun to change for the better, and young men who have studied abroad have been appointed to minor positions on the Peking board, as well as to provincial and local boards. Another drawback is the lack of properly qualified teachers—the pay of teachers in the lower schools is naturally small and the demand for educated Chinese in commercial

positions so great that in many of the lower schools it is almost a case of the blind leading the blind. This, too, is gradually righting itself as the number of graduates of the new system increase. A third disadvantage is the coordinate of the second; the students entering a school are seldom properly prepared to undertake the work prescribed for them. These early defects of adjustment will gradually be outgrown—rapidly outgrown when the control of educational affairs comes into the hands of really competent officials. The hampering effect of these officials is well seen in the case of the Imperial University of Peking (which must not be confused with Peking University, an American Methodist institution). This has, in some sense, been the outgrowth of the Tung-wên-Kuan, established under the scholarly Dr. W. A. P. Martin many years ago. Like an unsuccessful corporation, it has gone through a series of reorganizations and at last seems firmly established with a large staff of foreign and Chinese professors and, with modern buildings in course of erection, should do effective work.

A marked feature of the situation is that the most effective educational work is now being done by schools that are not a regular part of the system and have, therefore, to some degree at least, escaped official control. The number of such institutions is remarkably great, some of them having been in existence before 1902, and others having sprung up to meet real or fancied special needs since that time. Of these easily the first is the Imperial Pei-Yang University at Tientsin, which was founded by Dr. Charles D. Tenney (who had been tutor to the family of H. E. Li Hung-chang) before 1900 and was reorganized by him in 1902, after its destruction in the Boxer outbreak. This remarkably able man, who is now Chinese Secretary to the American Legation in Peking, also organized the school system of the entire province of Chihli, and it is to his effective work that the great growth of modern education in Chihli shown in the preceding table is largely due. The effective work of the Pei-Yang University has been due to its having been almost free from official control during development, at first under the administration of Dr. Tenney and later under Wang Shoh-lien, an equally able Chinese, who, though educated in England for the naval service, has done the most effective work of any Chinese in the development of the new system. When the national and provincial boards of education are composed of men of this calibre, educational progress will be rapid. Graduation from this institution is recognized by American universities as equivalent to attaining the B.S. degree; it thus enjoys the unique distinction of being the only Chinese institution of learning whose degree (Chin-shih) is recognized abroad. It should be added here that this, and all other schools, can not grant a degree *per se;* the school devotes itself to the work of instruction; degrees are granted upon examination by an official board created for the purpose. This school is now practically a part of the regular system.

Among other irregular institutions is the Shansi University at Tai-yuen-fu, now under foreign control, but which will soon be turned over to the provincial government. This is doing effective work, as is the Tongshan Engineering College, of which S. S. Yung, a graduate of the University of California, is president. This school is under the control of the Board of Posts and Communications. Nan-Yang College at Shanghai, Nanking University at Nanking, and a host of others make up a list which it would take too long to enumerate, and as the relationships of many of them are somewhat vague it would in many cases be difficult to decide whether a given school were really a part of the regular system or not. Among these are five naval colleges already established, and six additional ones proposed, numerous medical schools, for training surgeons for the army and navy, training school for officials, and other special schools. In many of these, in order to secure students, the tuition, books, and board were not only free, but the students actually received a stipend of a few dollars per month. The instruction in many of the schools was at first of little account, and they were derisively termed *chih fan hsueh t'ang* ("eat-food schools"). These also are now much improved in effectiveness, and the ability of Chinese physicians, notably Dr. Wu Lien-teh, formerly vice-director of one of these schools, was conclusively shown in the handling of the outbreak of the plague in northern China in the autumn of 1910.

From this brief review it will be seen that university work in China lies in the future rather than the present, as the most advanced work at present, that of the Pei-Yang University, is little better than of college grade, while this and all the other advanced secondary schools are largely technical in character. University work, in the ordinary sense of the word, is not yet being done, the demand for vocationally trained men being greatest. The difficulties of higher secondary educational work are numerous, among them the necessity of conducting it in some foreign language, usually English. This is not due, as might be at first supposed, to the necessity of employing foreign instructors, but is rather because, for a number of reasons which would require too lengthy explanation, it is not practicable to translate text-books of university grade into Chinese; to teach the students the foreign language being at once easier and better. This is one of the problems of the future; foreign instructors are expensive; the use of foreign language by native instructors will present many difficulties, while those encountered in the preparation of advanced text-books in the Chinese language are almost insuperable. Another problem is the insurgent spirit of the student body in many institutions. Though a proverb similar to that regarding the teaching of one's grandmother to suck eggs is well known in China, its full force is not always appreciated by the students, though in extenuation of their oftentimes insubordinate conduct it must be ad-

mitted that the administration and even the instruction in the new schools is sometimes woefully ineffective. As in Russia, the student body throughout the empire is filled with a revolutionary spirit and tinged with idealism. But it must not be inferred from this that the outlook is other than hopeful, for to one who realizes the strength of Chinese conservatism the progress already made is tremendous and the possibilities of the future illimitable.

Many will ask why the introduction of modern education in Japan was so much more rapid than in China, a proverbially scholarly nation. The reason is just that in Japan there was no old system to clear away; the nation began with a clean slate and an immense desire to learn, while in China the value of modern education was but tardily recognized and the new had to establish itself in the face of the opposition of the old. Some of the men who have had a prominent part in this have already been mentioned, but I can not forbear to speak of the great body of other Americans who are, far in excess of all other nationalities, taking a prominent part in the present work. Of the educational work under missionary auspices that of the Jesuit fathers was early prominent and is still important. Missionary bodies of every nationality are carrying on important educational work, chiefly primary, though secondary work is not neglected, as the American Methodist Peking University, the American Episcopal St. John's College at Shanghai, the Jesuit College at Sicawei, the English Episcopal Anglo-Chinese College at Tientsin, the Christian College at Canton, the Soochow University, the Union College at Wei-hsien in Shantung, and many others, serve to testify. These, like denominational colleges in America, held a dominant position at first, and like them can not hope to long hold a leading position in a national system of education. In these, as in the secular schools, Americans are most prominent and, paraphrasing the epigram as to the songs of a country, it seems clear that, with American influences predominating in the schools of China, the future development of that country, now in the throes of political readjustment, can not escape being profoundly influenced by American ideals.

PRECESSION: AND THE PYRAMIDS

By Dr. PERCIVAL LOWELL

BOSTON, MASS.

TO be told that five thousand years ago the Southern Cross could have been seen by one standing where London stands to-day would certainly cause most people surprise. Nevertheless such was the fact. That celestial asterism to which persons who have not seen it look forward as to one of the revelations incident to voyages into the tropics and then, on beholding it, feel egregiously duped, needed then no far travel to disclose. The sad disillusioning caused by its rising could have been enjoyed without leaving home. For 3000 B.C. its center-void apology for the real thing might have been observed above the outline of the South Downs at midnight at the proper season of the year by a star-gazer at the then mute and inglorious Greenwich.

If amazed at the apparition our tourist thus transported back in time turned to get his bearings from the north, not less astonished would he be to discover his old friend the pole-star unaccountably gone. Even the learned might experience a shock. Certainly to those who drink in their star-knowledge through the medium of the Dipper would it prove disconcerting to find Polaris adrift in the sky. Its fixity fled, our cynosure would indeed be difficult to detect. Just as mediocrity exalted by office sinks into plucked insignificance once its insignia are removed. Nor would he find the solace of familiarity anywhere else. For such upsettings of fundamental fact would confront him everywhere. The whole firmament would appear to be turned topsy turvy could we suddenly be canopied by the heavens of those departed days. All the constellations would seem askew even if he succeeded in making them out. Nothing new under the sun! perhaps; but a very different state of things under the midnight stars.

Such a thorough change in outlook upon the universe is certainly no mean event and serves to point the importance of a subject in astronomy well worthy of engaging general attention, the more so that it is intimately associated with man. For this revolution in the sky is brought about by what is called the precession of the equinoxes. The name is due to what first disclosed the action. Primitive man framed his calendar by the stars. Not having the benefit of an Old Farmer's Almanac with its superannuated tillage advice, the husbandman then judged his seedtime and harvest by the constellations that rose in the morning just before the sun. How long he placed implicit confidence in such chro-

nology after it became out of date we can but surmise. For that the stars and the seasons which they ruled did not continue to agree must have been early evident to the astronomer-priests who made a study of the two the basis of their calendar and of all the functions, aratral and religious, appertaining to it. So that the stellar springtime of one year was not the springtime of the next. That the zodiacal constellations were continually moving forward to meet the sun in his yearly round of the sky could hardly, one would have supposed, have escaped the observation of antiquity. Yet we find no mention of the fact; not so much as an ascription of the incongruity to the errors of predecessors.

To Hipparchus is due the honor of its discovery; a detection brought about in this wise. Besides watching the heliacal risings of the stars the ancients had another way of determining the date of the vernal equinox: this was by noting by the gnomon of a sun-dial the times when the shadows cast by the sun at noon were longest or shortest. This gave them the dates of the solstices. Hipparchus by comparing his own observations with those that had preceded him—on Spica, chiefly—found that the two methods did not agree but that the equinox as set by the sun stepped forward to meet the stars by about twenty minutes each year. As he perceived that while the longitudes of all the stars were thus changing, their latitudes remained the same, he concluded with the astuteness of genius that it was the equator that was moving, not the ecliptic; that is, the earth's tilt was shifting not the sun's.

The merit of Hipparchus in the matter was two-fold: the ability to discover the thing and then the courage to proclaim it. For in the good old times men were no quicker to recognize advance than they are to-day and were just as possessed to denounce it. In consequence Hipparchus's discovery suffered the usual fate of new truths. Some astronomers disputed his facts, others explained them away as an oscillation merely, while yet others simply ignored them. In spite of which mundane anathema the slow movement of the equinoxes went obstinately on.

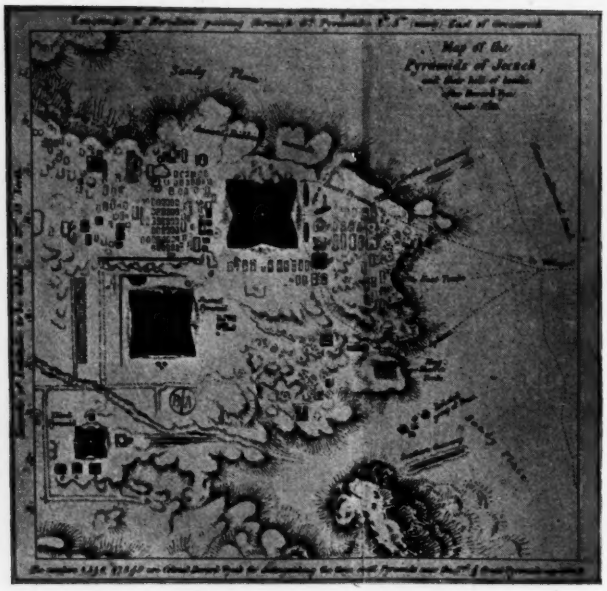
This mighty revolution of the equinoxial points by which spring opens twenty minutes earlier each year Hipparchus was not able to explain. He noted the fact, which was a feat remarkable enough, considering his means. Indeed, he probably never tried to penetrate further into the mystery. The Greeks were better geometers and more discerning reasoners than we were brought up at school to believe, but in astronomical matters a great gulf lies between them and modern thought. They never conceived the principle of universal gravitation. Failing this, it is no wonder they never imagined to what precession could be due. For the realization of this result of gravity is a much more advanced step in celestial mechanics than the accounting for the circuit by the planets of the sun.

Not wholly easy at first of comprehension, appreciation of the prin-

ciple which underlies it will be found well to repay the trouble it costs. For to master it is to put one's self in possession of a celestial time-piece one hour of which is 25,700 years and whose minute hand traces out the lapse of centuries upon the dial of the sky. Not only as a clock is it a possibility, but as we shall see it has been actually so used unconsciously by man in days gone by, and his readings of it recorded in lithographs still legible to-day.

To understand its working we must in thought get off the earth and see that body from without. We should then perceive our globe as a mammoth top spinning in the sky as it moves along in its orbit. The spin gives us our days, and as the equator is tilted to the path the pull of the sun is all the time trying to bring the one to coincidence with the other. If the earth were perfectly round there would be nothing for the sun to grasp and the spin would remain unchanged both in amount and in direction. The earth, however, is not round, but spheroidal, bulging at the equator. There is thus a handle, two handles in fact, which may be used for turning it. Now suppose the earth in the position of its summer solstice when its axis is tilted away from the sun in a plane containing the sun and a perpendicular to its orbit. The attraction of the sun tends to rotate it in this plane. Meanwhile the earth is spinning round its own polar axis at right angles to that direction. We have then to compound two spins about axes perpendicular to one another. Curious as it may seem, the result is not to pull the bulge down into the orbit plane, but to make it back bodily along the ecliptic. It is as if the earth resented the sun's attempt to right it and with almost human perversity went the other way. Indeed one may feel the obstinacy of the thing by appropriately pressing on a gyroscope, when instead of yielding it will promptly buck against you with a force suggestive of intent. The greater your shove the faster its opposing speed. Now with the earth the pull of the sun is feeble compared with the great moment of momentum of the earth, and in consequence the motion of the earth's pole is most leisurely. The backing of the equinoxes to meet the sun is but 50″.23 a year and the time it takes to complete the circuit of the zodiac 25,700 years.

The figure of the earth exposing it to such action, any body may set it spinning and all do. The amount and direction of the spin depend on the position of the disturber. Because the greatest, by precession is usually meant the luni-solar precession, caused by the combined action of the sun and moon. In this the moon is about two and one eighth times as effective as the sun in spite of its relative insignificance because of being so much nearer. The amount of the precession depends among other factors upon the cosine of the obliquity of the ecliptic. The greater the obliquity, therefore, the less the precession. At the present moment the obliquity is diminishing and the precession increasing. This will continue to be the case for several thousand years.



MAP OF THE PYRAMIDS OF JEEZEH.

Besides this precession another or, more properly speaking, several others are produced indirectly by the action of the several planets upon the plane of the ecliptic. As these bodies are out of the plane themselves their action pulls the earth out of her orbital plane, causing a change in the obliquity of the ecliptic. There is in consequence a slow alteration in the place of the pole of the ecliptic and this results in a movement of the equator other than what the sun and moon produce. It is known as the planetary precession. Chiefly by such round-about process do the planets make themselves precessionally felt. For all of them, even Jupiter, are relatively too small and too distant to have their direct pull upon the earth's equatorial ring of any account. The direct precession due to Jupiter is only about 0″.0001 a year and that caused by any other planet much less.

As all the planets are concerned in the work, and as they are all pulling different ways, the combined effect is not regular in either extent or duration, although there is a general swing to and fro of the ecliptic as the result. Its periods are much longer than the luni-solar precession. Thus, according to Leverrier, the one now going on had its maximum effect about 40,000 years ago and the next will be 35,000 years hence. This may be taken as about the mean swing; which shows that it is thrice that of the precession of the equinoxes properly so called. It is so combined with the latter, however, that though quite extensive in itself, amounting to more than 4°, it can never change the tilt of the ecliptic to the equator by more than 1°, one third on either side, so that our seasons

can never differ greatly from what we know them now. They can neither be materially accentuated nor proportionately reduced.

Though the obliquity of the ecliptic is oscillatory, the motion of the ecliptic pole keeps persistently, though unsteadily, on always in the same sense. Its wanderings trace out an elliptic spiral which never returns into itself. Its vagaries resemble as much as anything an unevenly bent spring carelessly coiled about a mid-position from which it never far departs.

Meanwhile our own pole pursues its relatively sedate march around the other, permitting its position to be calculated at any past epoch not too remote. We can plot its path and thus see near which stars it passed, stars which had the earthly distinction once upon a time of being our cynosure. In this manner we discover that 4,690 years ago, or in 2780 B. C., the pole passed within 3′ of arc of the star α Draconis. Practically the star was the pole, and it was the last bright star the pole approached before reaching Polaris. In the time of Hipparchus, 140 B.C., the pole lay undistinguished in a waste region of the sky. A of the dragon is now a star between the second and third magnitudes, but there is evidence to show that in ancient times it was brighter. It must

MAP OF THE NORTHERN PART OF THE ANCIENT PYRAMID FIELD IN EGYPT.

therefore have been a fine pole-star in its day, both because of its nearness to the pole and because of its own intrinsic brilliancy.

Of interest as this is from an academic standpoint, it becomes impressive when we learn that this prophecy about the past was contemporaneously verified and witnessed, as unconsciously as it was conclusively.

Not only was α Draconis once the pole-star, but it was actually so seen of men who have left us record of the fact. And this, too, without the slightest idea that they were dating history, and in the most dramatic manner possible. Not by carved or written inscription, not by oral tradition handed down by word of mouth, was this accomplished, but in a way at once more silent yet more sure—mutely embodied in the very core and being of a building the grandest ever erected by man. The Great Pyramid, the pyramid of Cheops, tells us this in stones that bear no character at all and only astronomy can read.

Herodotus, the "Father of History"—known also as the father of lies in what may be called the Ananias Club sense, for we are now learning that what he narrated, though seemingly unbelievable, usually turns out to be true—informs us that when he was in Egypt he was told by the priests that a long time before certain peoples had come down from the north, possessed themselves of the Egyptian power and so far affected the mind of the then King Cheops or Suphis that he forsook the Egyptian religion, caused all the temples to be closed and set to work under the stranger's direction to build a huge pyramid of stone.

The same veracious if also voracious historian goes on to say "that 100,000 men were employed for twenty years in building it; that Cheops was succeeded by his brother, Chephren who followed his pyramidal example; and that by the space of one hundred and six years all the temples of the kingdom were closed." In consequence the pious Egyptians deprived of their natural religious vents "detested the memory of these kings"; as they may well have done for other than religious motives, seeing that they were employed at forced labor on such a scale for such a length of time.

Manetho, who confirms the royal apostasy mentioned by Herodotus, gives us to suppose that we have here an invasion of the shepherd kings about the time of Abraham. Their force seems to have been intellectual, as they overturned the whole Egyptian system of things, he says, without a battle. So that they were probably Chaldeans, and the pyramids which they caused the king and his successors to construct were not Egyptian monuments at all, but embodiments of a foreign cult peculiarly distasteful to the followers of Isis and Osiris. Indeed, as we shall presently see, they were neither Egyptian nor monuments.

What they were not is plain; what they were has best been deciphered by Proctor, who has shown well nigh conclusively that their purpose was

astrologic. That they were astronomic constructions they themselves reveal, and the only rational explanation of the power the strangers gained over the mind of the king lies in the astrologic art the Chaldeans are known to have possessed, and which is also known to have been eagerly sought after by all the peoples of the east.

Both without and within they testify to a very heavenly regard on the part of their builders. In the first place their situation is expressive. They stand within a mile of the thirtieth parallel of latitude and undoubtedly were only prevented from standing nearer that astronomic line by the fact that the plateau shelf on which they were erected here falls abruptly to the plain. At this point on the earth the north pole is 30° high, and thirty degrees has this commendation to geometers, which the pyramid builders emphatically were, that a perpendicular from it to the line of sight is at that elevation exactly half as long as the line of sight itself.

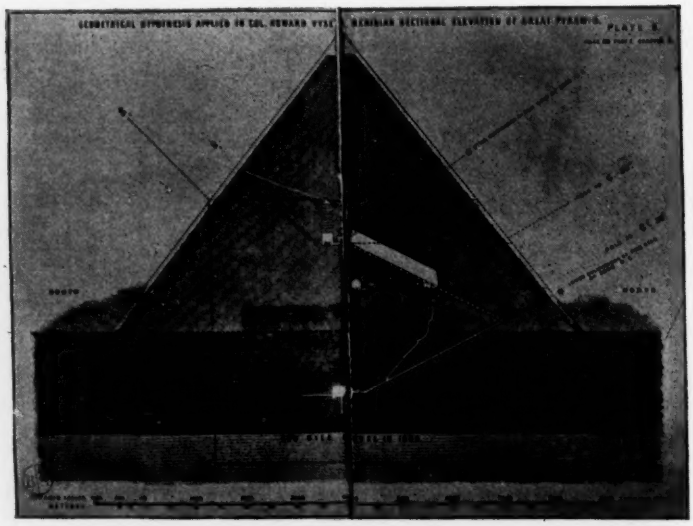
In the next place the base of the building is four-square, its sides being oriented to the compass points with surprising accuracy. Just as Christian churches face the east, that is Jerusalem, and Mohammedan ones Mecca, so the pyramids faced the north. Here then we have surmise of both religion and astronomy, to wit astrology, embodied in the mere outward aspect of these constructions.

This is, however, as nothing to what the interior reveals. Upon the north face of the Great Pyramid a passage opens, descending for 350 feet through tiers of stone at first, then through the solid rock. This passage points to the north within 4′ or 5′ in azimuth, is perfectly straight and is inclined to the horizontal at an angle of 26° 26′. The long straight hole suggests that it was used for looking at a star, for down it a bright star might even be seen by day. Its direction, moreover, hints that the pole-star was the one in question. Now the latitude of the pyramid is 29° 58′ 51″. The subterranean tube, therefore, does not look directly at the pole; but when we take refraction into account we find that it would look exactly at a star distant 3° 34′ from the pole when that star was at its lower culmination, that is, passing the meridian directly south of the pole.

Now if in latitude 30°, a man wished to observe the north or south passage of a circumpolar star, in order, for example, to ascertain true north, the best means of doing so would be to dig a subterranean passage-way pointing approximately northward and then mark through it when the star ceased to rise or sink; and since either culmination would suit him he would naturally choose that one in which the slant of his tunnel would be the least, both because he could dig it easier and because he could descend it best. An incline of twenty-six degrees is distinctly preferable to one of thirty-four. Now 645 years before or after the date when α Draconis was approximately upon the pole, it

was 3° 34′ distant from it; that is, in B.C. 3430 or B.C. 2140. The passage, then, chronicles the time when the pyramid was built—with a seeming choice of alternatives. But the nearer of these is negatived by what we know of Egyptian history and we are thus left with the other, that of B.C. 3430, as the date of the pyramid's construction. The pyramid thus dates itself astronomically, which is the first remarkable thing about it.

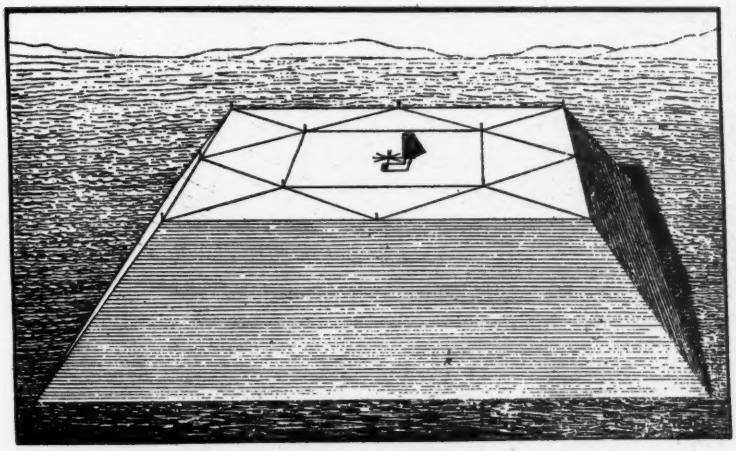
It is to be noticed that astronomy here furnishes Egyptology with a fixed epoch from which to go forward or back. We are not here dealing with conjectures as to when a certain king or dynasty can be made



GEOMETRICAL HYPOTHESIS APPLIED TO COLONEL HOWARD VYSE'S MERIDIAN SECTIONAL ELEVATION OF THE GREAT PYRAMID.

to fit into a general chronologic scheme by the relics it has left us of itself. Calculations from known astronomic data can tell to an exactness gauged only by the size of the opening of the passage as seen from below precisely when the pyramid was built with only the choice above described. To deny which would but argue a lack of appreciation of physical science. For that such a pointing can be but the sport of chance, the whole structure of the pyramid emphatically denies.

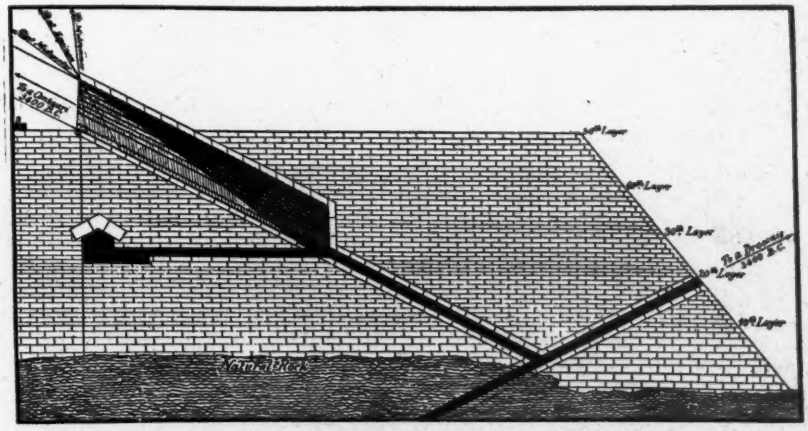
The Great Pyramid was in fact a great observatory; the most superb one ever erected. The building is the most mammoth in the world, and it had for telescopes something whose size has not yet been exceeded. This something which did those old astronomers for instrument was the Grand Gallery. As its name implies this was a stone gallery of imposing proportions set on an incline of 26° 17′ in the very heart of the structure and pointing south. It is approached by the



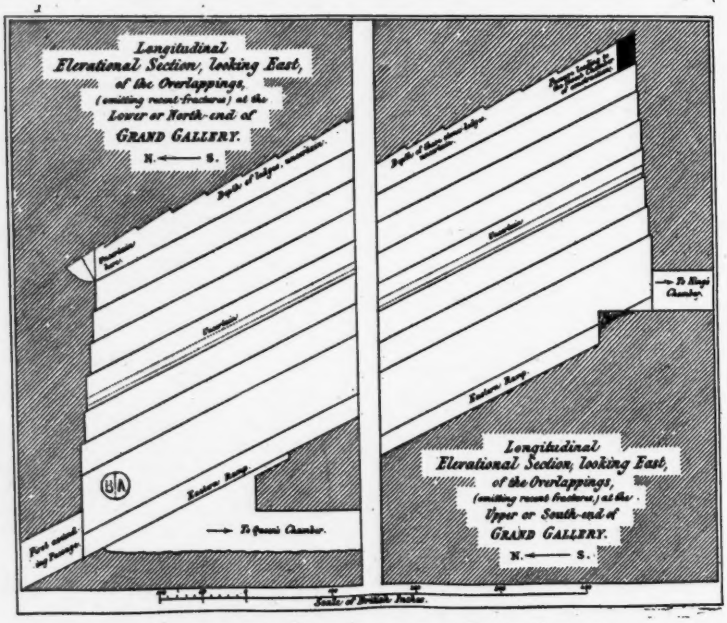
THE GREAT PYRAMID OBSERVATORY.

descending passage which looked at the pole-star and thence by an ascending one at about the same angle which opens into it. It is one hundred and fifty-seven feet long, twenty-eight feet high and about eight feet wide. Along the center of its floor a smooth stone flagging ascends, flanked on either side by raised curbs or ramps half as wide each as the central paved pit. These curbs are not continuous but are cut at approximately equal intervals of about five and a half feet by notches with vertical edges. There is no doubt that these were for the insertion of benches, as the notches tally on opposite sides. At about sixteen feet from the bottom the central incline stops in a vertical wall which descends to a horizontal pavement, giving entrance to the corridor which runs to the Queen's apartment.

The roof of the gallery is everywhere smaller than the floor, so that



VERTICAL SECTION OF THE GREAT PYRAMID, SHOWING THE ASCENDING AND DESCENDING PASSAGES, GRAND GALLERY AND QUEEN'S CHAMBER.



LONGITUDINAL SECTIONS OF THE GRAND GALLERY.

it overhangs the bottom about one foot eight inches on three sides, 39.5 inches at its southern top. The stones on the sides are carefully set in tiers, the sides themselves being oriented to the compass points. Its exact dimensions which we shall find telltale are:

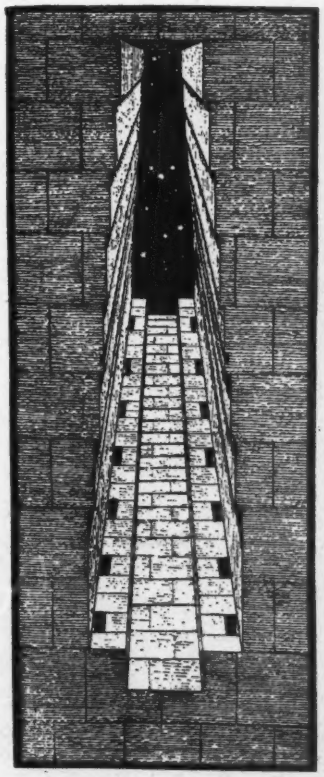
	Inches
Inclined length of floor	1,815.6
Same produced to south walk	1,883.0
Height	339.0

It is now of course walled in by stone on every side, but in the day of its use it undoubtedly stood open at the top, the horizontal passage in which it now ends at the summit having been the beginning of the platform of the whole pyramid, at that height. No records tell us this; our information comes from the gallery itself. Now if we calculate the angle from the vertical which the end of the cornice makes with the upper end of the floor we shall find it 6° (6° 20′). Remember that the gallery faces due south, so far as the builders could place it, that the latitude was 30° (29° 58′ 51″) and that the obliquity of the ecliptic was then 24° (24° 4′). Now subtract the second angle from the first to get the altitude of the sun at the summer solstice, and we have 6°. Consequently at that season the shadow of the gallery roof would just strike the south end of the gallery floor. A curious astronomic coincidence, you say. But go a little further. Let us calculate the angle from this same coping down to the end of the central incline on the

gallery floor. It comes out 36° 10′. Now at the winter solstice the sun was 30° + 24° from the zenith or 54°, that is, 36° from the horizon, the angle just found. In midwinter then the sun shone just to the bottom of the effective gallery, as at mid-summer it had marked its top. Between these two extremes the shadow must always fall. Thus the gallery's floor exactly included every possible position of the sun's shadow at noon from the year's beginning to its end. We thus reach this remarkable result that the gallery was a gigantic gnomon or sun-dial telling, not like ordinary sun-dials the hour of the day, but on a more impressive scale, the seasons of the year.

That the gallery itself extends below the point where the central incline drops vertically to permit of entrance to the Queen's Tomb with its ramps notched, as above, does not vitiate the deduction, for observers could not generally be placed on benches with their legs hanging down, however they might be so located on emergency. The recognition of this function of the gallery is not new, being, I believe, due to Proctor, but the exact coincidence of the limits of the effective gallery with those of the sun has, to my knowledge, never been pointed out.

Such, then, was the use of the entering passage, and such the design of the Great Gallery. Grand as was communion there with the sky by day, it must have been sublime at night—alone with the stars in the heart of that superb monument of stone. About the year B.C. 3430 it was further heightened by a spectacle which could not be witnessed now. Calculation shows that the great star α Centauri, the brightest and nearest to us of all the fixed stars, shone then at its upper culmination night after night down the hushed and polished vault of the Great Gallery.



THE GRAND GALLERY. VERTICAL SECTION THROUGH

α Centauri now hardly peeps above the pyramid's horizon at its highest, and in a few more years will never rise there at all until, thousands of years hence, the pole in its majestic precessional march raises it into view once more.

In a peculiar sense the pyramid was the man for whose use it was built. Primarily its purpose was to cast his horoscope through life, and then when his days were ended it became his tomb. He was

buried in its interior. What had been its astrologic platform on top was continued on to an apex and then the whole structure sealed up, to remain, so it was fondly hoped, inviolate through time.

One reflection well worth our thought the pyramids suggest: the enduring character of the past beside the ephemeralness of our day. We build for the moment; they built monumentally. True we have printing which they had not. But libraries are not lasting. Fire accidental or purposive has destroyed the greater part of the learning of the far past and promises to do so with what we write now; and what escapes the fire mold may claim. Only that idea which is materially most effectively clothed can withstand for long the gnawing disintegration of time. The astronomic thought of the pyramid-builders lives on to-day; where will record of ours be, I wonder, five thousand years hence. We may be quoted indeed with ever-increasing inaccuracy of transcription, but the star-priests of α Draconis's time speak in their own words still.

To us Cheops is hardly more than a name; long since his ashes were scattered to the winds; but the building those old Chaldean soothsayers constructed for him remains, not only to-day the grandest monument of man but the oldest and most significant astronomical observatory the world has ever had.

NEW YORK'S TEN THOUSAND

By WILLIAM J. ROE
NEWBURGH, N. Y.

FOR many years periodicals which make a point of entertaining timeliness have printed articles concerning the police force of New York City. Very few of these have been flattering, although at times, especially when some novelty of legislation has been inaugurated, or a new and more or less distinguished chief of the department entered upon his duties, they have expressed a guarded hopefulness of better things. But for reasons that to the initiated are sufficiently clear, few of these expectations have been realized; and of late the articles have been either in the nature of reminiscences, or what has come to be called "muck-raking."

The object of this paper is neither to relate incidents—historical or scandalous—and such interest as it may have will be solely of that sort which citizens having the welfare of the city at heart may take in whatever tends towards the establishment and maintenance of permanent good government.

Under our federal system republican principles of representative government are in full force, not only among and between the states, but in counties, townships, villages and school districts. In all these local interests are directed by local authority, representative government being the prevailing rule. Outside of the large cities authority touches the average citizen but lightly; in fact, in most rural neighborhoods the presence and pressure of legality is felt only once a year when the collector of taxes makes his official existence manifest, or when occasionally some local issue (in this state usually a question of "wet or dry") arises.

But in New York City, a very different condition of things exists. Here a constant need for the law's efficient maintenance surrounds and presses upon both householder and visitor. Rules and regulations, unknown because unnecessary in smaller or thinly settled communities, are here imperative. Questions of common rights, or mutual duties, of order, of sanitation, of the preservation of equality in some directions and of the equitable permission of privilege in others; these, and many more problems in utmost perplexity continually arise, demanding not only cheerful acquiescence from the law-abiding, but the constant strain of that eternal vigilance which is the price that must be paid for liberty.

While it would be uncivil and to a great extent misleading, and might be considered unpatriotic to assert that our republican form of government, so admirable in the nation at large, has in practise broken down in the great cities, calling attention to manifest truth can harm no one, however sensitive; to a very considerable extent New York City is denied one of the first essentials of republicanism—home rule; in many respects it is governed as a conquered province from Albany. Perhaps some—or even all—of these denials are inevitable; at all events they are legal, and the good citizen is bound to submit gracefully, however much he may deplore the fact that some of the most cherished guarantees of democracy are absent in metropolitan life. He may console himself with the knowledge that legislation entirely appropriate to rural neighborhoods is utterly impracticable as applied to a city of nearly five million inhabitants, closely, and in sections stiflingly clustered, of many races and faiths and of countless diversities of habit. Not only do the laws by which the metropolis is governed emanate largely from sources exterior to itself, but these laws are continually changing. Unlike the national administration, which is in essentials simple and comparatively stable, that of the city is extremely complex, the laws which it is the duty of the police to enforce being not only intricate, but are being tampered with and altered continually. The conditions in these respects that have prevailed and still do prevail are sufficiently perplexing to confuse and demoralize almost any body of men on earth; that they have not demoralized further than they have the police force is greatly creditable to their self-control, sagacity and respect for constituted authority.

In order to understand the exact nature of the very radical change which it is my purpose to outline, something in the way of both comparison and contrast between the national and civic administration may well be considered. Especially ought these comparisons and contrasts to be clearly understood between the regular army (the police of the nation) and the police force, which may be considered as the army of the city.

The civilization of the western world, the Teutonic race having been always in the van of progress, has achieved at least one lesson perfectly learned—the deplorable results of irresponsible power and the necessity for those limitations upon the will of an executive to be summed up in one comprehensive phrase—the law. In America, as we know, the limitations have for their source a written constitution, to be interpreted by an unprejudiced judiciary, and directed by congress.

But in the course of the broadening of freedom this curious paradox is disclosed, that while parliaments and congresses have grown continually more and more mindful of the people's will, the strength of the executive of that will has been continually enlarged. In the

days of the Tudors and Stuarts, the English people, slavishly submissive to the caprices and excesses of monarchy, always stubbornly refused to countenance a standing army. In the early wars in which England was engaged it was seldom that her land forces were better than armed mobs; and until Cromwell trained his Ironsides, hardly anything that at the present day would be called discipline was known. Now in America the president possesses powers for action greatly exceeding those of any limited monarch, and almost equaling those of an oriental despot. He is not only absolute within limits prescribed by civil law, but he is commander-in-chief of the army and navy, and as such may in certain emergencies suspend or annul the functions of congress and the courts. This is not only theoretical, it was proved during the war-between-the-states to be preeminently practical, notably in the instance of the emancipation of the slaves. The possession of such masterful powers indicates, not at all any peril of "imperialism," so called, but rather an expression of the cordial consent of an enlightened and free people, and the certainty that the law may safely permit a temporary suspension of its own functions, confident that—the danger overpast—these will be resumed without impairment of liberty.

The strong arm of the president of the United States for the enforcement of the laws of the land is the regular army. Note with what remarkable foresight our system was planned to avert the danger that so affrighted our British ancestors. The ordinary civil processes for the quelling of disorder—the sheriff and his posse, constables, police—failing, the state militia are called out; and these all having proved ineffectual, constitutionally recourse is had to the authority of the president and the army. And this force is at once the most masterful and the least domineering. Every now and then—some "radical" having urged more vehemently than ordinary "government ownership of railways," the return outcry voices the fear that the votes of so many employees would be utilized by the chief magistrate "to perpetuate his power." But while there may be a possibility that such fears are genuine, who for a moment associates the idea of politics with an army man? Often in the course of our history some successful general has been seized upon by a political party as an available candidate for the highest office. Almost half our presidents and presidential candidates have been more or less military men. Usually they have been politicians in inverse proportion to their military ability, for the most part perhaps, "Good men weighing so and so many pounds."

Note upon what inflexible principles the army is decreed, constituted, manned, officered and governed. It emanates directly from the people, the people's representatives, by authority and direction of the constitution, permitting it to exist only from congress to congress.

But once authorized, or the authorization renewed by renewed appropriations, congress is almost invariably wise enough to refrain from further interference. The art of war is recognized as a *metier,* a trade, the most exacting and absorbing of professions, demanding not only high technical skill, but for the utmost efficiency power completely within itself, the capacity to act as a unit. So governing the regular force is left to those competent from training and experience to guide it. Watched by a civilian secretary of war, the elements in control are the acts of congress, the articles-of-war, the rules and regulations of the service, and the individual authority, strictly limited and defined, of the officers from the chief-of-staff to the subalterns. The office of a man in commission is for life or during "good behavior"; ordinarily he can be removed only upon specific charges, and these must be proved before a duly constituted court-martial; in any event he may claim the protection of congress. But always these salient facts stand out unqualified—the entire separation of the civil from the military functions—the just jealousy and dominance of the civil power, the freedom within limits of the military, and also the clear line of demarcation between the legislative and judicial functions and those purely and properly executive.

The police force of the city of New York has some points of resemblance to the regular army, and many more where the analogy has no application. A policeman is in fact in hardly any sense a soldier; he is better to be described as a civilian, suitably armed, and clothed with powers and responsibilities relating primarily to the preservation of the peace, and incidentally to the detection of crime, the capture of criminals, the enforcement of the law and the arrest of violators of the law. This force, unlike the army, is the creation almost of yesterday; principles virtually settled as to the national body of armed men, have not as yet taken definite and coherent shape with them. The blundering incident to everything new, raw and tentative, may be traced in the numerous experiments made in compliance with enactments of the state legislature. These have been due mainly to party policy, but sometimes to well-meant ignorance (often miscalled "reform") and sometimes, it is to be feared, to deliberate or even immoral scheming. Sometimes a board of commissioners, all of one party, has controlled the department; sometimes—as at present—a single head, and at one time (1895–97) a so-called bi-partizan board, divided nominally equally between democrats and republicans, was in power. Not even the extraordinary ability of Mr. Roosevelt, chairman of the board, could overcome the obstacle of divided responsibility. He left at least one good trace of his incumbency, the tenacity with which he held to the important doctrine that it was not the province of a commissioner to criticize the laws under which he acted, but to enforce them.

Since then has come the era of the "single head" to the department, a manifest improvement, since it is always better to have one (even a bad) "boss," than many—even many good ones. In fact the "bosses" of New York's police force have seldom been bad—that is, as executives never, it may be said, incapable; even the worst of them could have been wonderfully efficient if he had so chosen. With his views as to the ends to be attained this paper does not deal; to those views he was very loyal. Loyal too, after quite a different fashion, have been the army men who have been in control. But loyalty to an ideal is one thing, leadership in any sphere of activity when the foundation principles are radically defective, quite another. If for no other reason than the complexity and multiplicity of duties devolving upon the head of the department some of these must inevitably be slighted or neglected. The chief-of-police (whatever his title or under whatever code of laws he serves) ought to be free of virtually all routine duty.

But the really radical defect in the plan of organization of the department as applied to the commissioner, the flagrant, vital defect, at odds with all practical efficiency, real strength, and "the eternal fitness of things," is that in his hands are concentrated powers that under the conditions are incongruous, that he combines in his own person executive, legislative and judicial functions. The system in vogue in London, whereby the chief is an absolute autocrat, having power of dismissal without appeal, is better than this. But neither conforms to the requirements of equity; no man should be held—even voluntarily—as another man's vassal, and no American citizen should be deprived of his just right to the final judgment of the courts of his country. Again, as the law stands[1] the commissioner can be removed from office at any time and for any cause or no cause at the will, whim or caprice of either the mayor or the governor. Probably at some future time, if the laws remain as they are, this power of summary removal might not be undesirable; but certainly so insecure a tenure of office does not conduce to discipline. It renders the dignified office of commissioner something very like that of a lacquey, and that not to one master, but to two.

Comparison of the regular army with the police force shows most conclusively that for the latter there should be a legislative body, willing, to the same extent that congress is willing, to abstain from continual interferences, and to be guided largely by expert opinion derived from those who actually do the work and are familiar with practical conditions. Whether this body shall be similar to the old-time board of commissioners, whether the board of aldermen shall assume these duties, or a board constituted upon entirely new lines, these are matters demanding much thought and careful consideration. But, however this legislative body may be constituted, its function should combine those which

[1] Charter of the City of New York, Chapter VIII., Police Department.

for the army are now distributed between the war department, with its several bureaus, the general staff and the committees on military affairs of congress. In this way the chief officer of the police force would be called upon for no more than advisory assistance, being left free for the work of supervision and command. As a general in the field, he should have under him an adequate staff, responsible only to him and reporting only to him, and being clothed with powers as his representative. In time of riot or disorder the powers of the chief should be greatly increased; in effect his personal authority, while not extending of course to that of "life and death," should really for the time supersede the civil. To a military man there is something ludicrous in the idea of gentle dealings with a mob. It may be political heresy to say so, but no chief of police should discriminate between a band of murderous ruffians—if you choose avowed brigands—and those—hardly less ruffianly—who use and utilize the striking of honest workingmen for better conditions for purposes of pillage and violence. If a mob knew that the orders were—"Shoot to kill!" unlawful assemblages would quickly become unknown.

So far as *discipline* goes the police have seldom been other than disciplined. But to impose *military discipline* upon a policeman is not only impossible except when he becomes part of a battalion or when mobilized to resist and suppress disorder, but is usually quite undesirable. The duties of a patrolman on post are not in the least like those of a private soldier. He is an officer, must be treated as an officer, and his duty must be compared to that of an army officer. He is almost constantly beyond the oversight and control of a superior; he is bound to act by himself and obliged to think for himself. He is not an enlisted man, whose duty is largely that of blind and prompt obedience, but a citizen temporarily bearing arms for a specific and limited purpose.

The method of discovering and applying correct principles *applicable to all bodies of men acting under authority* to the police force; to do away with improper conditions; to reconcile discrepancies, and to establish the administration of the department upon a stable foundation, ought to be the work of a suitably constituted commission. This commission should be appointed by the governor, or preferably the mayor, under authority of an act of the legislature. This commission ought to be composed in part of graduates of West Point, in part of captains of police in sympathy with the work, the police commissioner, and one or two civilians, of whom one at least should be a lawyer thoroughly versed in municipal affairs. There is an old adage that, "A commission is a noun of multitude which may signify *many*, but seldom signifying *much*;" but we have equally good authority that, "In a multitude of counselors is safety."

If not already familiar with the history of the department, it would

be the manifest duty of the members of this commission to "read up" the entire subject, making themselves fully acquainted with the progressive steps by which the old-time watchman evolved into the municipal force, that having been displaced by the metropolitan police. They will find a continual rather than continuous progress towards better things in ways of organization, each commissioner having left something tending towards improvement; until, coming to the present time, a degree of practical efficiency is found probably nearly as great as under existing laws the force is capable of attaining.

But the present conditions can not be safely reckoned upon for continuance. The wide-spread and deplorable corruption that at times has disgraced the department may at any election return. The very efficiency, the very decency of the present administration may be the chief factor in bringing about a change far more likely to be for the worse than for the better. The spirit of that notorious and wonderfully able faction that for almost a full century has imposed its malign influence upon New York simply awaits a renewed opportunity. Not even four years of purest political and business methods can so dilute the foulness of the past as to make palatable the promise of the future. Do not mistake my meaning. The contest for good government in New York is not between democrats and republicans, nor is it between a faction of democracy and a coalition of opposed forces; nor is it surely between Tammany Hall and the so-called "better elements." It is in fact a phase of that interminable quarrel between the narrow "Puritan" and the broad "Cosmopolitan" ideas of civic administration; between a too tenuous ideality and practicality; that to legislate for the morals of the citizen, and to enact laws in their nature "sumptuary" will always fail of their high purpose. The limitations of enforcible authority ought to be recognized and never overstepped. The purpose of the police should be confined strictly to the preservation of the peace and the orderly and lawful maintenance of law and order. So long as human nature exists human infirmity will always evade human statutes. Smite vice if you will, but inevitably the harder it is smitten the wider will it be spattered, the more room will it find for contamination; it may be diffused; it can not be annihilated.

With overt crime the record of the department has not been entirely inglorious; but in dealing with the vicious propensities the results have been very far from successful. The reasons are notorious—the men "higher up," even perhaps the man highest up, for political ambition or the profit of the pocket, may have connived at or incited a system of paid-for immunity. At one time there has been extreme laxity, at another rigorous—and sometimes illegal—enforcement of arbitrary and unavailing laws. These concerning such iniquities as the saloons, the social evil and "gambling" in all its numerous forms have changed and

fluctuated, capriciously, at the behest or caprice of some "boss," or—what is almost equally deplorable—the urgency of sentimental opinion. It is all iniquitous, or worse, it is ridiculous. Whatever we may think of the "effete civilizations" of continental Europe, these matters have been settled there, not well, that may be admitted, but wisely and prudently, in accordance with human reason recognizing its inability to cope with human instinct.

Although Tammany Hall is readily recognized as "notorious," and has certainly the reputation of having been grossly corrupt, few, it may be said, are aware of the extraordinary strength of that organization or its mastery of the problems of civic science. That it has been almost exclusively a "one-man power" accounts for much of its ascendancy and effectiveness. Left alone, untrammeled by interference from without, it could be counted upon to give to New York city a truly efficient and metropolitan government. For its analogy we may look to the old Mormon hierarchy of Utah. There were found—previous to "gentile" interference—side by side with a custom revolting to humanity's purest sentiment and degrading to civilization, a condition of peace, prosperity and outward decorum almost idyllic. So long as the "latter-day-saint" had his way, he saw to it that the way was made pleasant for everybody. It has been much the same with Tammany during its periods of power; the arts of municipal dominion and those of loot and spoliation have gone hand in hand, and both have been reduced to scientific principles. During every so-called "reform administration" numerous hold-overs from a previous Tammany régime have been retained in office; and it is safe to say that a large percentage of efficiency of both the Strong and Low mayoralties was due to the experience of these men. In fact, if any especially difficult or delicate piece of work was required, it was almost invariably a Tammany "heeler" who was called upon to do it. It was not the high-toned moralist or well-meaning theorist in civics, but the man of practical knowledge. The Tammany man—whatever his faults—was always "on to his job."

This subject—the science and art of municipal government—will be, if not the first, not the least important that the commission will have to investigate. It can find no object-lesson more worthy of attentive study than that furnished by the despised and rejected Tammany. With far-seeing sagacity that institution seeks out and attaches to its service young men who give evidence of abilities—either brilliant or solid. Through the district leaders youths are constantly being taken up, sedulously trained, and given opportunities—some for hard work, and some—the exceptional ones—for real distinction. It is thus that the organization is in great measure recruited and the system perpetuated. Could anything be more masterly? Then do not let us smile at or ignore it; still less revile it; but rather emulate it as to method in

order to emasculate it as to purpose. Be sure its cohesion is too indurated to become friable by a few years of adversity. The "Tammany tiger," drowsy as he may seem, sleeps with one eye open, never relaxing vigilant watchfulness for the chance to pounce upon the city fang and claw.

In times now somewhat past appointments to positions on the force and promotions therein were managed usually by district leaders, "pull" being largely a substitute for merit, and there was (if common report may be trusted) a price-current for the goods.

The stream of insidious and blighting influence is not to be restrained or diverted by any ordinary counter force, or by any moral suasion; the remedy must be radical, human nature's quality of cohesive habit be overmastered by that stronger habit—also human-natural—of the potency of early training, and that moral health is more "catching" than moral disease. The strength of the power adverse to purity and legality in New York lies in the police force, and that can be purified only by purifying the sources of influence, by a new and totally variant method of selecting aspirants for the shield and baton. It will be necessary to establish a *school of instruction*—a police cadet academy.

Candidates for admission to this school should be chosen by an examination strictly competitive; the dictum of the political "boss" would be dispensed with, being replaced by the findings of fact as to qualification of the civil service. Some of these qualifications may be stated: book learning, beyond the merest rudiments of "the three r's," should not be exacted; moral character, physical stamina, including suitable height, weight and chest measurement, and "brightness," ought to be the controlling requirements. Strength and bodily endurance should be of a quality to enable the youth to stand the strain of his exacting calling, not only for a time, but all through life until age should disable him. The age limit for admission should be fixed comparatively early; from sixteen to twenty-one would approximate the desirable ages. As to residence, etc., citizenship or that of parents, for one year prior to admission, as well as residence in the state for one year, should be as now required. In estimating character I would suggest an entire overhauling of some of the customary ideas of theoretical reformers; "piety" ought neither to count nor discount; neither the timid (whose pluck can be toned up) nor the "bully" (whose audacity can be toned down) should be barred out. While a mean or contemptible action—and of course conviction of a felony—ought to exclude beyond hope an aspirant, let it not be forgotten that no material is more promising than that found in the pronounced honest "tough." To some this idea may come as a rude shock—that it is educational "heresy." To such, however, the entire change may be shocking.

A number of models exist for the sort of training school contem-

plated. First and most influential is the Military Academy at West Point. Our regular army is officered in three ways: by appointment of civilians based upon the results of proficiency as determined by an army board; second, from a list of enlisted men and non-commissioned officers found duly qualified; but now mainly (and certain in the near future to be entirely) from the promotion of graduated cadets.

Although West Point has long been in the focus of publicity, and has a certain and very great renown for thoroughness of instruction and the general high average of the material it turns out, few indeed are fully aware of the essential nature of that institution's merit. This consists, not so much in the value of the education—though this ranks with that acquired at the best technical schools—as in the nature and extent of the course of training, influence and discipline. Here young men for four years of the most impressionable time of life are set and held wholly apart from all civil influences of a kind to divert them from the mastery of their profession. The West Point method is exacting to a degree almost cruel in its rigor; so exacting that of any entering class not more than half succeed in being graduated. It teaches—and enforces pitilessly—thoroughness, exactness, responsibility. But more and deeper than this, seldom is felt, except for purposes of instruction, the hand of outward authority. The commandant and his assistants, the "tactical officers," are seldom in evidence; for almost all purposes of organization, drill and restraint within regulation limits, the method is self-acting, largely automatic; from the room and tent orderlies to the adjutant and captains, the corps of cadets governs itself.

And this government is not of force, as the idea of compulsion is ordinarily understood. The real governing power is that most potent of moral forces—public opinion. From first to last, in big things and in trivial things, a cadet in matters of duty is always "on honor"; he is bound to report not only others' derelictions, but at certain times and for certain purposes, his own. The severity of the prevalent code may be inferred from the following, taken from a New York daily of July 3 last:

> A member of the new class was brought before a court-martial on a charge of making false statements to the officer of the guard.
>
> "Are you chewing gum?" the officer asked. . . . "I am not," — is said to have replied, and an investigation showed that the answer was false.
>
> This is the first time in a great many years that a cadet has been dismissed from West Point for telling an untruth, and the authorities feel keenly the disgrace.

I imagine that many will find in this instance, not justice, but undue and disproportionate punishment for what they may regard as a trivial offence. To chew gum in ranks is indeed trivial; to lie about it (under the West Point system) simply unpardonable. The West Point man is not better, perhaps, morally than the average of his fellow citizens out of

uniform; but the penalty for departure from the right line of conduct is so terrible, so inflexible, as to fasten upon him—if not naturally straight—a mechanical equivalent for straightness that, become habit, tends to render him immune to temptation. Some graduates have gone fatally wrong; but the percentage of such is amazingly small.

Then there is the Naval Academy at Annapolis, whose methods are virtually identical with those of West Point. Both these institutions ought to be visited and much time spent in acquiring the proper point of view. The post-graduate schools of the army should also have some attention paid to them; but more influential will be found the schools for molding the man-in-the-ranks, one of which is at Fort Slocum on Davids Island, near New Rochelle. Still more interesting and instructive will be the training-schools for naval apprentices. Of these there are four, one at Newport, R. I., another at San Francisco, and still others at Norfolk, Va., and at Lake Bluff, near Chicago, while the school for the revenue cutter service, now located at Arundle Cove, Maryland, but to be removed to New London, Conn., will furnish material for study. The navy department has printed an instructive booklet: "The Training of a Man-O'Warsman," well worth attentive consideration.

When the methods of all these, as well as many private institutions, have been carefully examined, and their force and meaning in each particular case been thoroughly digested, then will come the difficult task of application, of deciding as to what shall be included and what avoided in a school for New York's ten thousand. As to the location of the school, undoubtedly it ought to be so situated as to be quite separate and apart from civilian pressure, at least from civilian contamination. At the same time no attempt should be made to effect isolation or undue exclusiveness; on the contrary, proper provision should be made for visitors, relatives of the police cadets and others, and these should be invited to rather than prohibited from acquiring full knowledge of the processes of the institution. The locality selected ought to be within convenient distance from the city, with the view of affording easy access and opportunity for the graduating class (such as is now given during the six months probationary period) of accompanying regular patrolmen on certain tours to gain a practical, first-hand knowledge of actual duty. As a site none could be more suitable than either Wards or Randalls Island, though it is not probable that either—so admirably fulfilling some of the city's greatest needs, by the Manhattan State Hospital on the former and the department of public charities in the latter—could be made available. If the rapid growth of the city were not likely to render Pelham Park unsuitable in the near future, that site could be made to serve the uses of the proposed academy. But this consideration can safely "await the event"; if once the founding of

such a school is decided upon and legalized, the rest is bound to follow.

In a paper necessarily so brief nothing more than suggestion can be offered as to the course of instruction. Undoubtedly this should attempt nothing in the way of higher education; but graduates should be thoroughly grounded in arithmetic, perhaps algebra, with a fairly good knowledge of the rudiments of physics. There should be a course in elementary law, and due attention should be paid to American history and geography. But all theoretical studies should be subordinate to the practical essentials. Minute, detailed and constant instruction in "rules and regulations" and in every phase of an officer's duty with practise in "Moot-Courts" ought to be accompanied so far as possible by actual service, especially that in the final year duly authorized service on post should be provided for. Every student would be trained for duty in case of fire and riot, and in the use of motor-cycles, bicycles, and the use and care of horses and equipment. Throughout the course constant daily instruction would be given in infantry drill and the use and care of small arms, and the duties of members of such special squads as the tenement house, the health and boiler squads must be made familiar to all graduates. Much attention would be paid to all forms of athletics and "first-aid" to the injured and ill would be a specialty.

In addition to the general plan of instruction applicable to all, it would be highly desirable to establish special courses, to be taken by those students who distinguish themselves by marked adaptability. While every man should be taught to ride, a few might be selected for extraordinary practise, with a view to positions as mounted men. Every one should have a good general knowledge of "administration," but a certain number might be further instructed in all branches of accounts, bookkeeping, etc. Other branches, such as the bureau of electrical service, could be made the subject of a special course. The theory of "detection of crime" by a competent expert might be taught to a certain number of students in the final year. This is not to cherish the hope of making skilled detectives, such being "born, not made."

The general scheme of the school should, I think, be so planned that from the first everything would tend to the eventual substitution of graduates for civilians as higher clerks, secretaries, etc. The corps of police ought ultimately to be made to contain within itself every element of service, including proceedings similar to courts-martial for trial of delinquents. Perhaps also in the end certain duties now performed by policemen could be more efficiently done by civilian employees. For instance, while a mounted man would always be held rigidly responsible for the health, grooming, etc., of his animal, civilian hostlers, cleaners, etc., might well be employed. In short, though special courses ought to afford room for special talent, and in time the rougher menial duties be relegated to outside hired assistants, every-

thing should be subordinated to the fitting of a youth to be a *police officer*. The course of instruction ought to be at least three years, and four would not be too long.

The initial steps in the founding of the *School of Police* would be by far the most difficult. The experiences at West Point are, however, available. Happy would it be for the city's ten thousand if a man could be found so well equipped as was General Sylvanus Thayer, who served for seventeen years as superintendent of the military academy and to whom its efficiency is almost wholly due. The conditions respecting the police school are in some respects even more onerous, especially that even now about 475 new men join the force annually, a number certain to increase rapidly with the growth of the city. One great advantage enjoyed by cadets is the intimate contact and influence of classes. This would be largely neutralized in the police school unless by a division into battalions, or some similar device, this could be obviated. In the beginning probably a better foundation could be laid for future efficiency by limiting the number of candidates for admission; this number to be increased gradually with each succeeding year.

A change so radical in the mode of admission to the ranks of the force may be safely reckoned upon to encounter adverse and censorious criticism. The very radicalism, subversive as it undoubtedly would be, of all the traditions of the past, would incite to opposition. The epithet "aristocratic," and that other phrase, a potent shibboleth to fanatical conservatism—"not close to the people," will find its opportunity. Political opposition, too, may be counted upon, certainly from the "machines," probably from even the free-lances. From the less thoughtful of the force itself may be anticipated, not so much opposition as ridicule and a certain good humored contempt. It is not difficult to imagine that in precinct station houses, members off post, particularly the younger, more flippant and "smarter," will be found indulging in considerable hilarity over the proposed innovation. But (as Victor Hugo says) "He who drains a marsh must expect to hear the frogs croak." Much, doubtless, could be done among the older and wiser officers to offset this feeling. Certainly at the outset the endeavor should be made to acquire their interest and sympathy and cordial assistance in establishing and promoting the new order. This may be found not as difficult as it now appears; at heart the vast majority of men greatly prefer clean ways to foul. Men grow trustworthy by being trusted.

Nevertheless, the first of the classes to be graduated, and the members of the school's senior class who would be taught by actual practise on post, must expect to encounter something not unlike "hazing." But we may be sure that graduates will be quite able to hold their own; they will have been taught how to do that. And they can console them-

selves for any slight contumely by the reflection that theirs is not an isolated case. Even to-day the young West Pointer on joining his regiment finds himself often sadly at a loss in many practical ways of the service, in which the old sergeants of twenty years or more standing are easily his superiors. So far as they dare and as army discipline permits they will "put up jobs" on these commissioned youngsters. When in the forties of the last century the naval academy was instituted at Annapolis, the old sea-dogs, ancient vikings who had worked their laborious way upward to a commission, had no few or gentle jibes for midshipmen and ensigns who, as it was said, "had crawled into the service through the cabin windows." All that sort of talk has long ago been ended; our navy is officered now by graduates, and the Deweys and Schleys and Sampsons and Evanses have proved themselves no unworthy successors of the Decaturs and Perrys, the Porters and Farraguts. So I am confident the young graduated police officer will have it in him to say: "Damn the torpedoes! Go ahead!"

It is not, I think, difficult to forecast the nature of the results that —though perhaps slowly—would modify and in the end entirely subvert those evils that have smirched and defiled New York. There would be abundant criticism; but it may be assumed that every good citizen and the powers of the daily press would stand for fair play. As class after class was added to the blue ranks it would not be long before the influence of the increasing number of graduates would begin to be felt. It would be seen and noted in rapidly decreasing number of charges, trials and dismissals, and in the lessening disproportion between arrests and convictions.

Doubtless objection will be made on account of the extra cost of the proposed school and the length of time that must elapse before any very marked benefit could be perceived; but surely if the principle is right a few years devoted to preparation ought not to prevent or postpone action. The prudent investor looks less to the pretty architecture of the home that he proposes to purchase than to the conditions unseen or underground—the drains and sanitary plumbing. The effects of education are in the end certain and salutary. Good habits acquired at the proposed institution in youth will form character not lightly to be flung away in manhood, the sort of character over which the smirch and stain of temptation shall inevitably lose its power. The roundsman's vocation should be dignified, his service compared with that of the army officer, for both are keepers of peace. To the officers of the regular army the Chepultepecs and El Caneys and Indian and Malay ambuscades come seldom, and when they come bring glory with them. But the policeman's duty is done in obscurity and the dark. For him there is but trifling applause and never any brevets. He is always on the firing line, always liable to lead a forlorn hope;

the revolver of burglar or anarchist is always imminent, the stiletto of some murderous swarthy ruffian or the bludgeon of one of the gas-house or car-barn gang.

What a splendid record is theirs! One needs only to read the story of those dreadful days of the mid-summer of 1863 to feel the blood tingle and thrill. The names of Kennedy and Acton, McCredie and Walling and Carpenter stand high on honor's roll. Then in July, 1871, under Superintendent Kelso, how gallantly those police detachments guarded the stout-hearted Orangemen down Eighth Avenue amid a howling mob. And when the throng, grown truculent, hurled missiles—though Irish Roman Catholics almost to a man—those brave fellows never stopped to reflect upon their sympathies, but fell upon the rabble, clubbing right and left. Happily the forty years have shorn the "seditious cries" of "Orange and Ribbonmen" of their venom. We "have done with a worn-out tale, the tale of an ancient wrong"; but I know of nothing in history's annals more heroic, more significant of devotion to duty; the incident deserves to be recorded with the exploits of Goliad and the Alamo.

From these and like constant and common perils has arisen in the police force a certain well-defined *esprit de corps* of bravery and devotion that goes far—very far indeed—to redeem the "graft," so long a menace and a shame, and the rank perjury that (largely from a mistaken sense of comradeship) has so often covered up offenses.

If, then, one common right impulse may so prevail that there is not a shirk or coward on the force, is it not highly probable that other high impulses may be made also to prevail—that to lie and to steal may become as impossible as to fear?

There will be those who will say that this is impracticable, too tenuous, too idealistic. Fortunately there is at hand an example of a similar result of early education, of influence and environment having stamped upon human nature in process of development an enduring effigy of honor's highest standard. At the outbreak of the war between the states, while with rarest exceptions every southern civilian, and virtually every student at a northern university, "went with his state" most of them to join the insurgent army, one hundred and sixty-two West Pointers, being graduates from the seceded states—full half of those in the regular army appointed from the south—withstanding the claim of home ties and the call of the blood, stood by the union and the flag. On this long roll of honor the most illustrious was George H. Thomas of Virginia—the "Rock of Chickamauga." It is not necessary to impugn the motives of those other gallant gentlemen whose ideas of "state rights" differed from ours that we salute and dip the colors to loyalty like this.

ASSORTATIVE MATING IN MAN

By Dr. J. ARTHUR HARRIS
CARNEGIE INSTITUTION OF WASHINGTON

I. Introductory

"THE supreme misfortune is when theory outstrips performance," wrote Leonardo da Vinci.

He gave us, as far as I remember, no illustration of his epigram, but one is at hand in the modern attitude towards the Darwinian principles of natural and sexual selection. Exalted as they were on comparative evidence alone, and by post-Darwinian enthusiasts who were not only fertile, but liberal to a fault, in assumption, their debasement was inevitable. We are now in the period of reaction when men disparage selection, or dismiss it entirely as an evolutionary factor. Against this unreasonable extreme of opinion these essays[1] are directed. They are simple reviews, pretending merely to set forth honestly the results secured by biometricians in their studies of these exceedingly difficult biological problems.

Their purpose is, I admit, in reality two-fold. Not only are they a direct plea for a more open-minded—a stringently critical rather than a dogmatic—attitude towards the Darwinian factors, but an indirect appeal for a wider recognition of the biometric methods which make possible the measurement of the intensity of the primary factors of organic evolution.

The strongest arguments are those of quantitatively expressed facts. The best way of overcoming the prejudices and other obstacles against which the biometrician works is to allow these facts to speak for themselves, if possible in terms comprehensible to the layman.

Let us turn, therefore, to the available facts.

1. *The Problem of Intra-racial Sexual Selection*

There may be forces other than propinquity tending to fuse different races which through migration or otherwise come to occupy the same territory. Sociologists have, however, long emphasized intra-group marriages as one of the forces which tend to keep them distinct.[2]

[1] A first essay, "The Measurement of Natural Selection," has appeared in these pages, Popular Science Monthly, Vol. 78, pp. 521–538, 1911.

[2] For instance, Ripley ("Races of Europe," p. 49) says: "However strenuously the biologist may deny validity to the element of artificial selection among

This tendency to mate within the tribe is a factor of first-rate biological and sociological importance, serving as it does to maintain racial boundaries. But if sexual selection be a real factor in the evolution of races—in the differentiation of groups as well as in their maintenance—its action must be sought within the race, an intra-racial sexual selection must be demonstrated.

Sexual selection in man may, as Pearson long ago pointed out,[3] be of two kinds, preferential mating and assortative mating. By preferential mating one understands that certain classes of women are discriminated against by the average man, or by men as a class, or *vice versa*. By assortative mating one means that in the population of men and women who do marry, there is a definite tendency for certain classes of men to marry particular classes of women, and conversely.[4] An almost prophetic quotation from Pearson may render the distinction clear.

> For example, preferential mating might lead in a highly social community to the rejection of consumptive mates, while assortative mating might through localization or community of habit, lead to considerable consumptive correlation. Thus sexual selection as a whole may influence in diverse ways the inheritance of the consumptive taint.

Another illustration faces us in the problem of deaf mutism. Normal individuals discriminate against deaf mutes, for obvious reasons. There is a stringent segregation of the class, resulting from educational and social conditions, and as a result there is for the people, as a whole, a strong assortative mating, hearing people as a class marrying hearing, and deaf marrying deaf.

The scope of this review is limited to a discussion of the quantitative results which have been attained for assortative mating.[5]

It is needless to say that a subject so fascinating to man as any-

the lower animals, it certainly plays a large part in influencing sexual choice among primitive men and more subtly among us in civilization. Just as soon as a social group recognizes the possession of certain physical traits peculiar to itself—that is, as soon as it evolves what Giddings has aptly termed a 'consciousness of kind'—its constant endeavor thenceforth is to afford the fullest expression to that ideal.''

Westermarck (''History of Human Marriage,'' pp. 362–373, 1901) gives a terse summary of the social prejudices, tribal practises and laws concerning marriage between different castes, tribes or clans. Others are to be found in various sociological works.

[3] Pearson, K., *Phil. Trans. Roy. Soc. Lond.*, A, Vol. 187, pp. 257–258, 1897; also ''Grammar of Science,'' 2d ed., pp. 421–437, 1900.

[4] Thus in man sexual selection is a somewhat more complicated process than it has been assumed to be in the mass of writings on the lower animals.

[5] The quantitative data bearing directly on the problem of preferential mating are few. See K. Pearson, *Phil. Trans. Roy. Soc. Lond.*, A, Vol. 187, p. 258, 1897; ''Grammar of Science,'' 2d ed., pp. 425–428, 1900; *Biometrika*, Vol. 2, pp. 270–272, 1903.

thing pertaining to human mating has been the subject of wide speculation and assertion since the time of da Vinci.

Schopenhauer states that every person requires from the individual of the opposite sex a one-sidedness which is the opposite of his or her own. The most manly man will seek the most womanly woman, and conversely. Weak or little men have a decided inclination for strong or big women, and strong or big women for weak or little men. Blondes prefer dark persons or brunettes; snub-nosed, hook-nosed; persons with excessively thin long bodies and limbs those who are stumpy and short, and so on! Analogous superstitions are wide spread,[6] though differing in form. Westermarck,[7] in summarizing the views of various writers adds, "If contrasts instinctively seek each other, this may partly account for the readiness with which love awakens love."

Some have even ventured the opinion that where the husband and wife are unlike, the offspring are more numerous, or stronger! Again there is the popular superstition that after a long life together husband and wife come to resemble each other physically.[8]

Of course conclusions the opposite of all of these are not wanting.[9]

Such is the state of knowledge to which the unaided observation of a complex phenomenon can lead us—a snarl of contradictions. As far as we know, the only method of disentangling it and arriving at some certainty is the analysis of large bodies of observations by means of refined statistical methods.

[6] The way in which mere impressions may become stamped with authority by the approval of careless writers is illustrated by the following quotation, from a standard authority on sociology.

"It is almost proverbial that tall men choose short wives, and the union of tall women with short men is only a little less common. Thin men and plump girls fall in love, as do fat men and slender women. Blondes and brunettes rush irresistibly together."

[7] "History of Human Marriage," pp. 353–354, 1901.

[8] Fol ("La Resemblance éntre Epoux," *Rév. Scientifique*, Vol. 47, pp. 47–49, 1891) has tried to investigate this by means of photographs of newly married and aged couples, and while he concludes that there is a considerable resemblance between husband and wife, it is no more intense in aged than in newly-married couples.

[9] For example, Francis Galton, whose data and methods were not yet adequate for dealing with so complicated a problem, wrote ("Natural Inheritance," p. 85, 1894 ed.) with a caution which led him into error: "Whatever may be the sexual preferences for similarity, or for contrast, I find little indication in the average results obtained from a fairly large number of cases, of any single measurable personal peculiarity, whether it be stature, temper, eye-color, or artistic tastes, in influencing marriage selection to a notable degree. Nor is this extraordinary, for though people may fall in love for trifles, marriage is a serious act, usually determined by the concurrence of numerous motives. Therefore we could hardly expect either shortness or tallness, darkness or lightness in complexion, or any other single quality, to have in the long run a large separate influence."

2. *The Measurement of Assortative Mating*

The precise meaning of the term "assortative mating" may perhaps be made a little clearer in the process of explaining how the similarity or dissimilarity of husband and wife is measured.

Suppose a most highly refined socialistic community should set about to equalize as nearly as possible not only men's labor and their recompense, but the quality of their wives. It would never do to allow individuals to select their own partners—superior cunning might result in some having mates above the average desirability, which would be socially unfair!

The method adopted would be to write the names of an equal number of men and women officially condemned to matrimony on cards, and to place those for men in one lottery wheel and those for women in another. The drawing of a pair of cards, one from each wheel, would then replace the "present wasteful system" of "competitive" courtship. If the cards were thoroughly shuffled and the drawings perfectly at random, we should expect only chance resemblances between husband and wife for age, stature, eye and hair color, temper and so on; in the long run, a wife would resemble her husband no more than the husband of some other woman. In this case, the mathematician can give us a coefficient of resemblance, or of assortative mating, which we write as zero. The other extreme would be the state of affairs in which men of a certain type (that is to say men differing from the general average by a definite amount) always chose wives of a definite type; the resemblance would then be perfect and the correlation, as we call it, would be expressed by a coefficient of 1.

Fortunately, the meaning of correlation can be illustrated by a character for which the reader knows that there is a high degree of assortative mating. The table[10] shows the age of bride and groom in 2,500 Chicago couples. The swarm of figures showing the frequencies of different combinations spreads diagonally across the table, demonstrating that while men or women of any class marry consorts of varying ages, there is a pronounced tendency for individuals of the same relative age[11] to mate. From such a table the statistician calculates the equation to a straight line (or to a curve of a higher order) which describes approximately the change in the average age of brides associated with increase in the age of the grooms. The diagram (Fig. 1) shows that the agreement of the theoretical line with the empirical means is very close indeed.[12] Or he may express the closeness of correlation quite independently of the absolute values of the two characters on the scale of

[10] From a paper by F. E. Lutz, "Assortative Mating in Man," *Science*, N. S., Vol. 22, pp. 249–250, 1905.

[11] Since women marry younger than men, relative, not absolute, age must be specified.

[12] Such differences as occur are probably due to errors of random sampling.

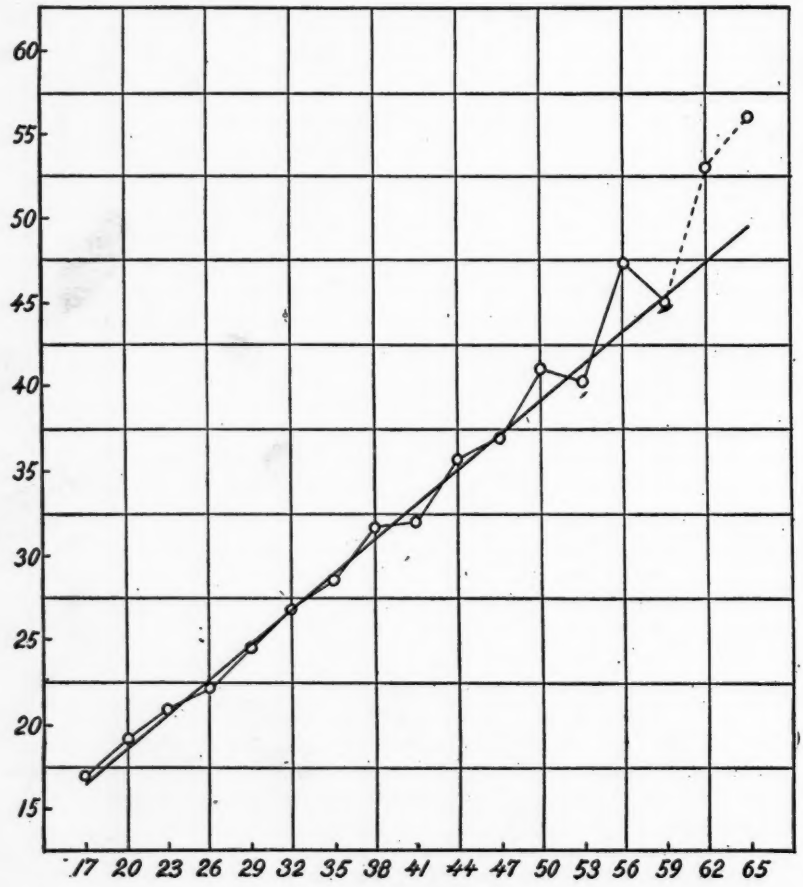


FIG. 1. AGE OF GROOM.

TABLE I

	13–15	16–18	19–21	22–24	25–27	28–30	31–33	34–36	37–39	40–42	43–45	46–48	49–51	52–54	55–57	58–60	
64–66	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
61–63	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
58–60	—	—	—	2	—	—	—	—	—	2	—	1	1	1	1	2	10
55–57	—	—	—	—	—	—	—	—	—	2	2	—	1	—	2	—	7
52–54	—	—	1	—	—	3	1	2	1	2	3	4	1	1	1	—	20
49–51	—	—	—	2	1	2	—	4	1	3	2	4	4	2	1	—	26
46–48	—	—	—	1	3	3	3	2	4	5	3	2	2	—	—	—	28
43–45	—	—	—	4	2	5	6	6	6	5	6	2	—	1	—	—	43
40–42	—	1	3	7	10	8	4	9	10	8	1	—	2	—	—	—	63
37–39	—	1	2	12	16	15	9	8	15	—	6	3	1	1	—	—	89
34–36	—	2	13	26	29	23	21	11	3	5	4	—	1	1	—	—	139
31–33	—	3	21	35	48	34	20	7	4	4	—	—	—	—	—	—	176
28–30	—	14	74	117	100	52	16	3	4	2	—	—	—	—	—	—	382
25–27	—	59	217	197	101	20	3	1	1	—	—	—	—	—	—	—	599
22–24	—	76	334	169	32	4	4	1	—	—	—	—	—	—	—	—	620
19–21	1	113	147	25	5	3	—	—	—	—	—	—	—	—	—	—	294
16–18	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
	1	271	812	597	347	172	87	54	49	38	27	16	13	8	6	2	2500

-1 to $+1$. In this case, the correlation is $+.75$, or about three fourths of the distance up the scale of 0 to 1, from no resemblance to perfect identity.[13]

To determine whether men and women tend to parity or disparity in matrimonial choice, we must, therefore, take a large number of mated pairs at random from the general population, sort them into groups according to some characteristic—quantitatively measurable whenever possible—and determine by means of the statistician's coefficient of correlation whether generally similar or dissimilar groups of men and women tend to mate, and how strong this tendency to parity or disparity is. Throughout this paper the intensity of assortative mating will be expressed by the coefficient of correlation. The reader will have to bear in mind merely that positive coefficients indicate a similarity and negative coefficients dissimilarity in husbands and wives as compared with random pairs of men and women from the population.

II. Assortative Mating for Physical Characters

1. *Stature*

The psychological basis of the popular notion that men and women seek disparity rather than parity in the stature of their mates is not far to seek. On the streets the linear wife and spherical husband, or the reverse combination, appeal to our sense of humor while the multitude of similarities pass unnoticed. Yet when lumped on the statistical scales the modal multitude may outweigh the extreme combinations whose incongruity provoke a smile as they pass to the front circle after the curtain has gone up.

With the rough statistical methods then available, Galton[14] was unable to detect any tendency towards marriage selection with respect to stature, but Pearson[15] on the same data as early as 1897 suspected homogamy. The results from his own more extensive family records are shown in Table II.[16] For convenience the figures for forearm and span are also given.

[13] This value is perhaps a little too high. However much popular opinion may overestimate women's reticence concerning their ages, statisticians know that even the correct age of marriage of both men and women is hard to obtain. Especial difficulty is to be expected near the extremes of the series. Those embarrassed by years may declare themselves of legal age, or even deduct a few years. Those who are not yet of legal age may falsify to obtain a license. As Lutz aptly remarks, these figures, "instead of telling the exact truth, show us the state of things modified somewhat by man's idea of how he thinks they had better be."

[14] Galton, F., "Natural Inheritance," p. 206.

[15] Pearson, K., *Phil. Trans. Roy. Soc. Lond.*, A, Vol. 187, p. 273, 1897; also, "Grammar of Science," 2d ed., pp. 429–431, 1900.

[16] Pearson, K., and A. Lee, "On the Laws of Inheritance in Man. I., Inheritance of Physical Characters," *Biometrika*, Vol. 2, pp. 372–377, 1903.

TABLE II

	Husband's Character	Wife's Character	Assortative Mating (Correlation and Probable Error)
Direct correlations	Stature	Stature	$+.2804 \pm .0189$
	Span	Span	$+.1989 \pm .0204$
	Forearm	Forearm	$+.1977 \pm .0205$
Cross correlations	Stature	Span	$+.1820 \pm .0201$
	Stature	Forearm	$+.1403 \pm .0204$
	Span	Stature	$+.2023 \pm .0199$
	Span	Forearm	$+.1533 \pm .0203$
	Forearm	Stature	$+.1784 \pm .0201$
	Forearm	Span	$+.1545 \pm .0203$

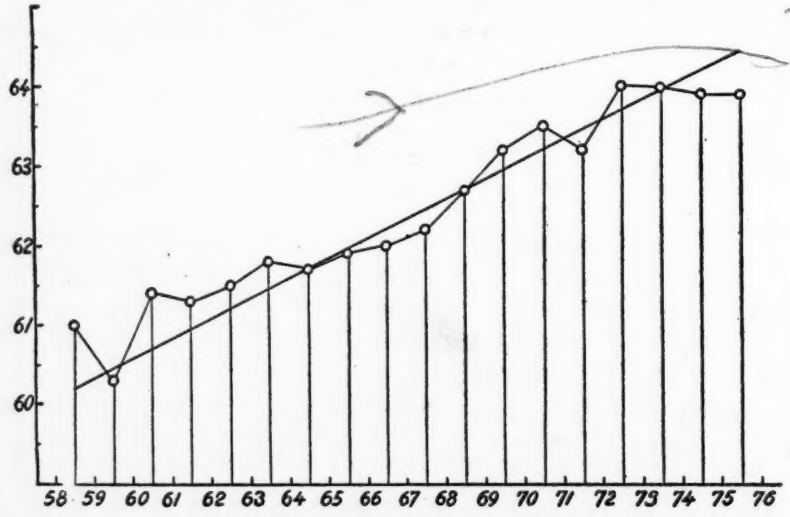


FIG. 2. SCALE OF HUSBAND'S STATURE.

We find a resemblance $r = +.280$.[17] Thus there is a very pronounced similarity in stature between husband and wife.[18] This is made clear by diagram 2, which shows the empirical and the (smoothed) mean statures of wives of husbands of different heights.

2. *Other Bodily Characters*

Data for physical characters other than stature are few;[19] the only

[17] From Mr. Galton's "Family Records," Pearson found the resemblance for man and wife to be $+.09 \pm .05$, but between fathers and mothers of adult children, as in the case of his own material, it was $+.18 \pm .02$. Considering the smallness of Mr. Galton's pioneer series, the results are not in bad agreement.

[18] Galton's series of data ("English Men of Science," pp. 22–24, 1895) for the parents of English scientific men is too small (embracing only 62 cases) to give conclusive results for assortative mating. It indicates, however, no tendency towards contrast.

[19] I have omitted Galton's ("English Men of Science," p. 21, 1895) data for the "figure" of 71 pairs of parents of English scientific men, since the

important ones are forearm and span in Pearson's investigation.[20] For the direct[21] comparisons the resemblance is quite material, amounting to about + .200. Cross correlations are in general somewhat lower. Possibly the assortative mating is primarily for stature, while the resemblance for forearm and span arise merely because these are closely associated with stature. This point is not as certain, however, and deserves more attention.

For forty-eight families of East European (Russian) Jews living in New York City, Boas[22] found an assortative mating for cephalic index (relative head breadth) of $r = + .15 \pm .10$.

Lutz's interesting data on the inheritance of the method of clasping the hands[23] show a positive sign in the correlation between the two parents, but it is so very small that no significance is to be attached to it.

3. *Complexion and Hair and Eye Color*

Complexion and hair and eye color are conspicuous with stature in the popular superstition of "the charm of disparity" in human matings.

The calculation of the intensity of relationship in the case of a character which like eye color is not quantitatively measurable presents considerable difficulties, and the results vary with the method employed. From an analysis of Francis Galton's "Family Records," Pearson[24] has deduced the following values:[25]

Correlation by four-fold method	$+ .10 \pm .04$
Mean contingency	$+ .31$
Mean square contingency	$+ .26 \pm .03$

numbers are too few to calculate the contingencies on the basis of his grouping, and the classes are too indefinite for satisfactory combination.

[20] Length of forearm is the distance from the bony projection of the elbow, with the arm folded as much as possible, to the tip of the middle finger. The span is the greatest possible distance between the tips of the middle fingers of the outstretched hands.

[21] By direct correlation we mean the degrees of resemblance calculated for the same organs in husband and wife, by cross correlation those in which the characters are different. The entries in the table makes this quite clear.

[22] Boas, F., "Heredity in Head Form," *Amer. Anthrop.*, N. S., Vol. 5, p. 532, 1903.

[23] Lutz, F. E., *Amer. Nat.*, Vol. 42, pp. 195–196, 1908.

[24] Pearson, K., *Phil. Trans. Roy. Soc. Lond.*, A, Vol. 195, pp. 113, 149–150, 1900; "Grammar of Science," 2d ed., pp. 431–437, 1900; *Biometrika*, Vol. 5, pp. 475, 1907.

[25] Yule (*Journ. Anth. Inst.*, Vol. 36, p. 359, 1906) has drawn these results into question on the supposition that they may be due to a personal equation or bias of the observer, which might lead him to classify both members of a pair alike. His criticism is well answered by Pearson (*Biometrika*, Vol. 5, p. 475, 1907).

The only series of data for hair color in husband and wife (where one may not suspect artificial selection of cases) is that given by Mr. Galton[26] for the parents of English scientific men. I have grouped his data into three classes, and calculated the coefficient of mean square contingency, which is + .34. No stress is to be laid on the result, since the number of cases is small and the coarse grouping—which is necessary if the constant is to be calculated at all—unsatisfactory.

4. *Physical Defects and Pathological Conditions*

To Alexander Graham Bell[27] probably belongs the credit of first laying great stress upon the social consequences of assortative mating. The title of his memoir, "Upon the Formation of a Deaf Variety of the Human Race," sufficiently indicates the seriousness with which he regarded the intermarriage of the deaf.

Probably assortative mating for deafness is more nearly perfect than that for any other known character. The reasons for this are patent. Hearing individuals rarely choose non-hearing mates. When both partners are deaf, on the other hand, they are united by the strong bond of fellowship and sympathy growing out of their similar condition, they communicate with each other with perfect ease and freedom, and the social interests and sympathies outside their own home are the same.

The extensive records given by Fay[28] rather than those used by Bell in his pioneer study may furnish illustrations.

Table III. shows that in the marriages of the deaf, 72.5 per cent.

TABLE III

Marriages of the Deaf	Number	Percentage
Both partners deaf	3,242	72.512
One partner deaf; the other hearing	894	19.995
One partner deaf; the other unreported whether deaf or hearing	335	7.493
Total	4,471	100.000

have both of the contracting parties deaf as contrasted with 20 per cent. in which one is deaf and the other a hearing person. When we consider that in the general population of the United States there are roundly 1,500 hearing persons to one deaf, and consequently about 1,500 hearing persons to one deaf from whom a given deaf individual might seek to select a life partner, we see to what enormous extent sexual selection is at work for this character.[29]

[26] Galton, F., "English Men of Science," p. 21, 1895.

[27] Bell, A. G., *Mem. Nat. Acad. Sci.*, Vol. 2, pp. 179–262, 1883.

[28] Fay, E. A., "Marriages of the Deaf in America," Washington (Volta Bureau), 1898.

[29] Schuster (*Biometrika*, Vol. 4, p. 473, 1906) was unable to calculate the precise intensity of the assortative mating coefficients for deafness because of the mathematical difficulties involved, but it is certainly considerably higher than + .90.

Bell laid great emphasis upon the influence of educational segregation, especially upon the use of a sign language, with its subjective influence on thought, in bringing about the intermarriage of the deaf. That this is a factor appears from Fay's elaborate records. He classified 7,277 deaf individuals according to the method of education and found that of those who attended boarding schools for the deaf, 86.2 per cent. married deaf mates, while of those who attended day schools, or both day and boarding schools, for the deaf 77.8 per cent. married deaf consorts.[30] In contrast are the records of those who attended no school for the deaf: in this class, 62.4 per cent. married deaf individuals. The difference between 62.4 per cent. and 86.2 per cent. probably indicates roughly the influence of scholastic segregation.

Fay also finds that of the pupils who attended exclusively oral schools 78.2 per cent. married deaf partners, while of those who were educated at schools not exclusively oral, or partly at schools exclusively oral and partly at schools not exclusively oral, somewhat over 86 per cent. of marriages were homogamous for deafness. Perhaps these figures indicate a sensible influence of the method of instruction.[31] Nevertheless, one cannot but be impressed with the intensity of the assortative mating that occurs independent of this factor. With no such isolation 62 per cent. of deaf individuals marry those who are deaf. Considering the intensity of the inheritance of deafness,[32] we see what grave social results may be expected from this tendency.

Apparently unions where both members are deaf are more happy than those where only one is so afflicted. Table IV. gives the best avail-

TABLE IV

Marriages of the Deaf	Number of Marriages	Divorces		Separations		Divorces and Separations	
		Number	Percentage	Number	Percentage	Number	Percentage
Both partners deaf	3,242	33	1.018	51	1.573	84	2.591
One partner deaf, the other hearing	894	25	2.796	33	3.691	58	6.488
One partner deaf, the other unreported	335	7	2.090	7	2.090	14	4.179
Total	4,471	65	1.454	91	2.035	156	3.489

able records indicating the "success" or "failure" of like and unlike matings. Of course divorce, separation or number of children do not tell the whole tale; they give rather a lower limit to the measure of domestic infelicity.

[30] In the cases where the mode of education is not known, 77.3 per cent. chose deaf partners.

[31] If the probable error of the percentages were calculated, their distinctness would appear much more open to question.

[32] See besides Fay's analysis of his data, a paper by Schuster, *Biometrika*, Vol. 4, pp. 465–482, 1906.

For general health in husband and wife, classifying as very robust, robust, normally healthy and delicate, Miss Elderton[33] calculated from Pearson's "Family Records" a relationship of + .27.

For freedom from constitutional diseases—*i. e.*, freedom from any specific pathological taint without regard to the strength or delicacy of constitution—Goring[34] found these resemblances for families of criminals:

Very poor and destitute	+ .17
Well to do and prosperous poor	+ .08
All	+ .11

The possibility of infection reinforcing constitutional likeness in consorts is presented by a disease like tuberculosis. From the evidence now available[35] there can be little doubt that if one member (husband or wife) of a pair be tuberculous the other is more likely to be affected than if the first be sound. In short, there is a correlation for tuberculosis between spouses which has sometimes been called "marital infection."

But such a term implies entirely too much. The correlations are not so high but that one may suspect them to be due, in considerable part, to assortative mating for the physical and psychical characteristics which underlie, or at least accompany, the predisposition to tuberculosis. Those who have analyzed the problem most minutely are inclined to attach importance to both factors, but to lay especial stress upon assortative mating.

5. *The Influence of Numerous Local Races*

The reader who is a keen traveler will probably suggest that the general population of England, whence most of the data have been drawn, is made up of local races differentiated with respect to physical characters,[36] and that marriages tend to be contracted between neighbors —*i. e.*, within the local race.

Pearson has emphasized the possibility of this factor[37] but with

[33] Elderton, Ethel M., "Stud. Nat. Det.," 3, London, 1908.

[34] Goring, C., "Stud. Nat. Det.," 5, London, 1909.

[35] The three chief papers are: Pope, E. G., "A Second Study of the Statistics of Pulmonary Tuberculosis: Marital Infection," edited and revised by K. Pearson; with an appendix on Assortative Mating by E. M. Elderton, Draper's Co. Res. Mem., "Stud. Nat. Det.," 3, London, Dulau & Co., 1908. Greenwood, M., "The Problem of Marital Infection in Pulmonary Tuberculosis," *Proc. Roy. Soc. Med., Epid. Sect.*, Vol. 2, pp. 257–268, 1909. Goring, C., "On the Inheritance of the Diathesis of Phthisis and Insanity: A Statistical Study based upon the Family History of 1,500 Criminals," Draper's Co. Res. Mem., "Stud. Nat. Det.," 5, London, Dulau & Co., 1909.

[36] That such differentiation exists is strikingly shown by anthropological maps, for instance those in Ripley's "Races of Europe," pp. 300–334, 1900.

[37] Pearson, K., *Proc. Roy. Soc. Lond.*, Vol. 66, pp. 28–32; also *Biometrika*, Vol. 2, pp. 274–275.

justice points out that his data for stature were taken largely from the professional classes—chiefly residents of London and other larger towns. While these marry in their own "sets," these can hardly be regarded as "local races." The records from cemeteries, to be discussed in the following section, were taken purposely from narrowly limited districts; tables were formed for each locality separately. Certainly such correlations can not be attributed to the heterogeneity arising from the mixing of differentiated samples. In other cases, the possible influence of local races has been well excluded.

Even if the demonstrated resemblances were due merely to the tendency to marry within the local race, and indicated no conscious or unconscious sexual selection on the part of individuals of the same race, they would nevertheless be of great interest as showing quantitatively the force of one of the factors tending to maintain racial boundaries.

III. Assortative Mating for Duration of Life

That human matings should so depend upon the visible physical and intangible, but none the less real, psychical characteristics as to give rise to a measurable bodily and mental similarity of spouses, while contrary to popular belief, seems not unreasonable. That this resemblance should extend to duration of life—a character quite unknowable at the time of marriage—appears at first thought highly improbable.

But duration of life is not a simple attribute. It is rather a conveniently measurable epitome of many physical and physiological traits, as well as of environmental conditions. Both its inheritance and the evidences which it furnishes of the action of natural selection in man probably depend upon its being the resultant of a complex of factors. May not assortative mating for appreciable personal characters result in an assortative mating for duration of life?

The answer given by the correlation between the age at death of husband and wife (Table V.) is affirmative—clear and emphatic.

TABLE V

Source of Material	Number of Pairs	Coefficient of Correlation Measuring
Wensleydale and district cemeteries	876	$+.2200 \pm .0244$
Oxfordshire cemeteries	890	$+.2500 \pm .0211$
Society of Friends' records	1,000	$+.1999 \pm .0212$
Mean		.2233

Warren, Pearson, Lutz, Lee and others[38] drew their records from the tombstones of rural English churchyards and from the archives of the Society of Friends—two quite dissimilar sources. Yet the results are in remarkable agreement; considering the errors common to statistical constants based on numbers of a thousand or less, one can not assert

[38] "Assortative Mating in Man: A Cooperative Study," *Biometrika*, Vol. 2, pp. 481–498, 1903.

that they differ at all. The close agreement with stature, forearm, span and other physical characteristics is clear.

A criticism which may occur to the reader is that these resemblances are purely spurious, and due to the fact that husband and wife are not likely to be buried in the same ground unless they die within a short period of each other. This is precisely what would occur in districts with a shifting population. This very difficulty was anticipated. All urban churchyards were excluded because of the heterogeneous and transitory nature of the population. "In most rural districts, on the other hand, with a stable population, there is a very strong feeling—amounting in the case of the Yorkshire Dales almost to a superstition—that husband and wife must share the same grave." In view of the careful selection of localities and the agreement of results secured from Quaker archives with those from the gravestones, it seems clear that the resemblance can not be dismissed as purely spurious.

Duration of life is doubtless dependent upon environment as well as upon constitution. Slight differences in the healthfulness of the several parishes of a district might promote or oppose fullness of years in men and women alike. If this were true, the lumping together of the records from a number of churchyards would result in a correlation for duration of life, whether there be any real assortative mating or not. If this criticism be valid, random pairs of husbands and wives from the same parishes lumped together to form a table for the whole district, should show correlations as high as those for actual married pairs. The correlation really found was sensibly zero, demonstrating that local environmental conditions can not explain the results.

But within the same general environment, members of a family are exposed to a set of conditions peculiar to themselves. In a city block or country parish food, temperance, sanitation, risk of zymotic disease, and physical and mental habits differ greatly from family to family. In addition to the physical and social environment common to man and wife, there is also the fact that the death of one member of the pair has a profound effect on the other. Financial and associated domestic changes are often due directly to this cause, to say nothing of the overstrain of care during long illness or the shock of sudden death. May not the similarity in the duration of life of husband and wife be a consequence of domestic environment? This point was investigated by methods rather too complicated for explanation here, but which indicate that the sameness of home conditions can not account for the relationship.

Until further evidence is available, we must, therefore, conclude that there is a real, though assuredly unconscious and quite indirect, assortative mating for duration of life. Nor is this to be marvelled at, considering the results already noted for normal and especially for abnormal bodily characters.

IV. Assortative Mating for Psychical Characters

That psychical characteristics should play some part in human matings seems *a priori* highly probable.[39] Actual facts are, however, few.[40] Galton concluded[41] that even good and bad temper made very little difference in marriage selection, but he pointed out many difficulties of obtaining trustworthy evidence.

Elderton[42] found for "Intelligence, Temper, Temperament"[43] and success in career the values given in the accompanying table.[44]

Mental Character	Relationship
Intelligence	.33
Temper	.18
Temperament, excitable	.11
Sympathetic	.15
Reserved	.27
Success in career	.48

For insanity, working with Pearson's "Family Records" and using two different methods of classifying the "normal," "insane," "nervous" and "doubtful" entries so as to get the upper and lower limits for assortative mating, Miss Elderton[45] finds $+.244$ as the lower and $+.361$ as the upper limit, say roughly an intensity of $.30 \pm .05$.

[39] Theoretically, assortative mating should be absent in royalty where marriages are contracted by persons other than those most directly concerned, or are arranged in accordance with some political policy. Woods ("Mental and Moral Heredity in Royalty," pp. 272–273) thinks it can not be held to be entirely absent. He correlated the intellectual grades of 229 couples and found $r = +.08$, approximately, but with a probable error of $\pm .076$.

[40] I have given none of the coefficient for psychical characters calculated by Schuster and Elderton (*Biometrika*, Vol. 5, pp. 460–469, 1907) from data collected by Heymans and Wiersma. These give results which vary widely among themselves and if one takes those which seem the most likely to be trustworthily determined, he opens himself to the criticism of the selection of evidence. Personally, I have grave doubts concerning the value of data on psychical characters collected by the widespread circulation of schedules. The estimates are too much subject to personal equation and family bias. When they are entrusted to especially trained observers who work comparatively, the case is better.

[41] Galton, F., "Good and Bad Temper in English Families," *Fortnightly Rev.*, July, 1887. Reprinted in "Natural Inheritance."

[42] Elderton, Ethel M., Draper's Co. Res. Mem., "Stud. Nat. Det.," 3, pp. 30–35, 1908.

[43] Galton ("English Men of Science," p. 20, 1895) had only 22 cases where the temperamental characteristics of the parents were marked. He considers that there is a tendency for harmonious matings with respect to temperament.

[44] The signs, sometimes difficult to determine in the case of non-measurable characters, seem to be positive throughout, but in some cases there may be distinct cross currents, one tending to produce like and the other to give dissimilar unions. The intensity of resemblance for "success in career" is about double that for other characters, and is possibly to a large extent spurious, because subjective. The "success in career" of a wife is probably largely dependent on or judged by the opportunities which her husband's success gives her for displaying her own abilities.

[45] Elderton, Ethel M., *loc. cit.*, p. 35.

Goring[46] considers that assortative mating is a factor of greater importance in the upper than in the lower social classes. In his records for insanity in criminals, he finds an assortative mating + .35 for the "well-to-do and prosperous poor" while it is probably absent in the "very poor and destitute." [47]

V. Preferential Mating and Assortative Mating for Social Attributes

To mark off sharply social attributes from those which are physical and psychical is as impossible as it is idle. Certain traits dependent on wealth, family history, education or opportunity may be, for convenience merely, designated as social. To what extent do they influence mating?

Their potency is greatest in caste, royalty and peerage. Even in countries which pride themselves on the absence of social strata, wealth, family pride and feuds, religion and education, play their part in limiting the range of choice in marriage selection. But nowhere is mating within the class universal. The much-multiplied American dollar plays havoc with continental pedigrees. The pure breeding of the English nobility is a pretence; "the lawyer, the farmer, the silk-mercer lies *perdu* under the coronet, and winks to the antiquary to say nothing." Some day the weight of these social forces will be determined, but the proper kinds of facts are not yet available.

Alcoholism is one of those interesting cases in which direct personal or social influence may supplement and reinforce the resemblance possibly due to assortative mating. Goring,[48] dividing his material for English criminals[49] into three classes for social status, finds these coefficients of resemblance:

Very poor and destitute	+ .44
Prosperous poor	+ .58
Well-to-do	+ .69
All	+ .70

[47] As a check, Goring determined the correlation between phthisis in one and insanity in the other member of a wedded pair. The resemblance was found to be sensibly zero.

[48] Goring, Chas., "Stud. Nat. Det.," 5, p. 27.

[49] The reader in noting the high values given for alcoholism by Goring will remember that the individuals studied are the parents of criminals, and that there is a known association between criminality and alcoholism. From data collected by Heymans and Wiersma, Schuster and Elderton (*Biometrika*, Vol. 5, p. 468, 1908) calculated a correlation for tendency towards drink of + .24 to + .36. But there are several reasons for doubting the trustworthiness of these data.

[46] Goring, C., "On the Inheritance of the Diathesis of Phthisis and Insanity: A Statistical Study based upon the Family History of 1,500 Criminals," Drapers Co. Res. Mem., "Stud. Nat. Det.," 5, London, 1909, Dulau & Co.

For criminality, Goring's results will strike many as surprisingly low. They are:

Very poor and destitute	+.18
Well-to-do and prosperous poor	not calculated
All	+.20

An interesting point of an entirely different nature has been raised by Heron[50] who in a study of the distribution of sex in human families finds, "that in the free mating of man, families with a preponderance of female or male elements are not drawn upon equally with families in which the sexes are more equally balanced."

VI. Homogamy and Fertility

From the notion that in marriage "opposite poles attract" the step to the conclusion that dissimilar are more fertile than similar unions is so easy that it has sometimes been taken, though without any valid evidence in justification.

Fay[51] considers that marriages of the deaf are possibly slightly less fertile than those of hearing persons. When both partners are deaf the percentage of sterile marriages seems higher and the mean number of children in fertile mariages lower than in unions in which one member of the pair is a hearing person.[52]

Homogamy for stature[53] and for eye color[54] have been considered in relation to fertility.

But as yet the data are far too meager for such complex problems. The whole problem of the relationship between homogamy[55] and fertility is open to investigation.

VII. Significance of the Results

The statistical facts reviewed in this essay make it highly probable that a great variety of physical and mental characters influence human

[50] Heron, D., "On the Inheritance of the Sex-ratio," *Biometrika*, Vol. 5, pp. 79–85, 1907.

[51] Fay, E. A., "Marriages of the Deaf in America," pp. 16–18, 29–30.

[52] Age at marriage, economic status and other factors probably complicate the problem.

[53] Pearson, K., "On the Correlation of Fertility with Homogamy," *Proc. Roy. Soc. Lond.*, Vol. 66, pp. 28–32; also *Biometrika*, Vol. 2, pp. 373–376.

[54] Pearson (*Phil. Trans. Roy. Soc.*, A, Vol. 195, pp. 148–150, 1900; *Proc. Roy. Soc. Lond.*, Vol. 66, p. 323, footnote) has considered Galton's data without arriving at final conclusions. De Candolle (*fide* Westermarck, "History of Human Marriage," p. 335) states that the number of children is considerably smaller when the parents have the same color of eye than when they were contrasted. Wittrock (*Ymer*, Vol. 5, pp. vii–ix, 1885) was unable, on Swedish materials, to detect any difference in fertility between the two classes of marriages.

[55] Homogamy means merely the mating of physically or psychically similar individuals. Sameness of stock, endogamy, is of course not implied.

matings, and in such a way that, on the average, similar individuals tend to marry.

These results will probably be received with much scepticism. The "charm of disparity," the "selection of opposites," has been so long asserted that the notion will not readily be given up. Concretions of vague impressions compacted into popular superstition are not soon broken up by the hammer of logical deduction from scientific measurement. This scepticism of preconception can, however, be ignored; in time it must give way to orderly arranged facts. Yet the scientist should not forget that when cracked open, the nodules of popular belief are often found to contain a scrap of truth—and in his turn should avoid dogmatism.

Purely biological phenomena are far more complex than the majority of naturalists have realized. When social factors are superimposed the difficulties of research become almost unsurmountable. Pearson has warned us that "in many factors there may actually be two opposed currents, one giving a tendency for like to mate with like and the other marked by the fascination of extremes." Goring's studies of criminals vindicate one's *a priori* conviction that assortative mating may be influenced by social conditions. Human society differs so profoundly from place to place and time to time that, however great the temptation to generalization may be, it would be folly to press the conclusions far beyond the data which they represent.

Moreover, if the biometric results reviewed in the preceding pages must be fitted post haste into some evolutionary scheme, or find an immediate practical social application, each reader must be responsible for his own. The difficulties of interpretation are even greater than the dangers of generalization. To-day, an unfortunately insistent demand that every datum must count for or against some current theory has largely replaced the Darwinian spirit of collecting facts in the hope that when sound and sufficiently numerous, reasonable theories may be fitted to them. To-day "a fact is not a fact until it fits a theory." Personally, I feel as thoroughly satisfied that the time is not yet ripe for interpretation as I am completely convinced that in the differentiation and painstaking measurement of the intensity of the individual possible factors we have begun to move in the right direction in the attack upon the phalanx of problems which we designate as organic evolution. The immense value of these pioneer studies by Pearson and his associates lies in the fact that they represent the definite and substantial beginning of quantitative research which is so large a part of the solution of a problem.

THE PRICE FALLACY OF HIGH COSTS

By RALPH H. HESS, Ph.D.
UNIVERSITY OF WISCONSIN

THE synonymous use of the terms *price* and *cost,* in their relation to the acquisition of things which may constitute a living, is responsible for a large factor of error in popular discussion and opinion concerning the so-called "high cost of living." Because statisticians have discerned a rise of approximately forty per cent. in the average of commodity prices within the decade, it is being taken for granted that the cost of living has advanced coextensively; and this conclusion has, in turn, become the premise of serious projects in contemplation of social and economic reform.

Although *price* and *cost* may, in conventional phrasing, be interchangeable without confusion of ideas, the discussion of changing commodity prices and concurrent costs of living necessitates a discriminating use of the terms. As a matter of fact, an increase in the average of prices may be no proof of change in the average cost of living during the same period; and, in any case, price changes offer only indirect evidence and unreliable criteria of cost factors and movements.

The *price* of an article merely indicates its money-value—its market equivalent in terms of the standard metal. The *cost* of an article, however, is the measure of conscious effort and sacrifice necessary to gain its possession—the exertion of labor, the discomfort of abstinence, and the forfeiture of time and resources essential to its production or acquisition. Prices are paid out of *income;* but income is conditioned only indirectly upon the backache and brain-fag of labor, and the time-consuming and capital-wearing processes of industry—these latter constitute *real costs.* Since both income[1] and prices are commonly expressed in terms of the dollar, it is necessary to consider the possible correlation of the two in any instance if one would arrive at an accurate understanding of the costs of living. Likewise, price-changes, during any period, must be measured against income-changes for the same period before a conclusion may be justified regarding changing costs of living. The problem is to trace the successive relations of economic effort to consequent income, of income to prices, and of prices paid to the subsequent utilities which constitute a living.

If the industrial, commercial and leisure classes of the population are collectively considered, total income and aggregate prices are subject to similar concurrent changes. It is a truism, often overlooked, that the sum of prices paid constitutes the total of wages, interest, rents and

[1] "Income" is here used in the sense of periodically accruing purchasing-power.

profits which compose the money-income of society and, *per se,* the direct means of acquiring the necessities and comforts of life. The measuring and estimating of changes in the cost of living, therefore, is resolved into a comparative study of incomes and expenditures. If incomes, expressed in terms of money, are found to increase more rapidly than contemporary expenditures or to decrease less rapidly, costs of living may be said to be declining; if converse relations exist, virtual costs are advancing.

It is doubtful whether a careful comparison of aggregate income and expenditure in the United States, during the régime of advancing prices following the depression of 1897, would show any considerable differential in their relative changes or any remarkable increment in the *average cost of living.* But it is quite possible that *aggregates* and *averages* may remain unchanged while a radical readjustment of incomes and costs is effected among individuals or among the differently circumstanced groups which compose the social organism. Indeed, it is quite plain that a readjustment of respective shares in the distribution of the total income among the different classes of the population is the *raison d'être* of present economic discontent, and a careful analysis of the apportionment of the "national dividend" affords a key to the current problems of living costs. If an increased proportion of the social income finds its way into the pockets of fortunate individuals and favored classes of society, other persons and groups must suffer a relative decrease in purchasing power. Since all buy in the same market, a part of the population possesses an increased proportion of cash to the prices which must be paid, and the exchequers of the less fortunate are inversely affected. In other words, persons identified with one economic class may experience an actual decrease in their cost of living, despite rising prices, while others must carry an increased burden, and, possibly, a third group may be affected not at all.

Space forbids an analytic treatment of the factors which have contributed to the unusual price movement of the last twelve years; they include such industrial and social phenomena as have affected the relative supply of and demand for the standard metal, on the one hand, and the supply of and demand for the things which make up a living on the other. That the unprecedented increase of the gold supply is a potent factor can not be denied; that there are other factors of equivalent significance is quite certain. Among the latter, are such socio-economic tendencies as effect a relative or per capita decline in the annual supply of the necessities and comforts of life and a consequent increased social cost of production, as well as an advanced scale of prices.

The following may be properly enumerated as characteristic attributes of social and industrial evolution which may contribute to changing costs:

First. Over-intensity of industry, nationally considered, thus passing the "summit" of maximum per capita productivity.

Second. Aspiration to ultra-standards of living, thus stimulating consumption regardless of productive efficiency.

Third. Centralization of industrial and commercial control resulting in suppressed output and monopoly-price.

Fourth. The accumulation of private fortunes and the consequent appearance of a leisure class and its concomitant of unsocial labor, capital and natural resources.

Among the above causes of changing values, there are certain items which exert a noteworthy influence in the readjustment of fundamental costs and incomes which is vastly more important than any question of prices. There are statistical data of unquestioned reliability which clearly demonstrate the course, although they do not afford an exact measure of the extent, of important kaleidoscopic changes in the distribution of income and the coextensive shifting of economic benefits among different classes of the population. It is this arbitrary shifting of cost-burdens, coincident with recent price fluctuations, that accounts for the prevailing outcry against advancing costs of living. Naturally, individuals and groups who fare badly in the process of pecuniary readjustment are prone to complain, and those who account an accelerating balance of income over costs are sanguine.

Whether the United States has reached or passed the industrial condition of maximum per capita productivity is a mooted question; some who have given much study to the problem of production are inclined to support an affirmative conclusion. That the multiplication of population and the exhaustion of natural resources have carried certain nations of Europe and Asia beyond the summit of production is well known. The Malthusian principle is inexorable, and when population threatens to overrun the natural springs of subsistence, the normal resultant is a scale of high prices and the exaction of excessive industrial costs in exchange for the means of living. Whatever may be the present relation of population to productivity in the United States, the cosmopolitan nature of modern trade and the fact that other countries have amassed populations in excess of their means to provide an average of comfortable living, have potential significance in problems of costs and subsistence. The further observation that the migration spillway of Europe conveys the surplus increment of prolific and improvident races to the United States at a rate of half a million a year, to be nurtured by "high-tariff wages" and the "fruits of abundant resources," suggests a factor of no mean proportions among the determinants of costs of living in America.

Advancing standards of living are properly considered as indicative of social progress; but economic limitations of social evolution are

omnipresent, and there is good reason to believe that current price movements portend an imminent check to the development and satisfaction of extravagant social desires. Collectively and individually, we are living better than ever before. We are working shorter hours, occupying better homes and cleaner cities, wearing better clothing, eating better food and being better educated—not only is this true of the wealthy and well-to-do, but of the poor and the indigent as well. But this rational form of "consuming-power" should not be confused with improvidence, or what has been associated in some minds with the alleged engulfing "cost of high living." Rational standards of living are justified by coextensive industrial efficiency. Progressive well-being tends to affect consumption and production in direct proportion; indeed, the stimulus to increased production normally exceeds the desire to spend, and no lasting influence towards advancing prices or costs results. If, however, expenditures are permitted to infringe upon the capital of the country, or of any particular group of the population, or even upon the rate of accumulation of savings, the effect on prices and costs will be immediate.

The centralization of industrial control, resulting in "wide-scale" enterprise and exclusive "occupation of the field," tends to eliminate output and advance costs. It makes little difference whether the differential advantage of centralization is of the nature of special privilege or superior efficiency of organization. In either case, industrial rivalry is forced from the field and, in the absence of official restraint, the exaction of monopoly charges is inevitable. The consequent shifting of the incidence of industrial returns may be ascertained by enumerating the respective beneficiaries and exploitees of the profit-taking process—the trade advantages of the one class measure the economic disability of the other class; and the attenuation of the incomes of the less favored, as a means to augment the profits of the more favored, is a significant attribute of changing social costs.

By the grace of strategic advantages of occupation and centralization, persons deriving incomes through proprietorship in relatively highly organized and capitalized industry are the recipients of differential gains which tend always to transcend price increments. Such persons are secure in the realization of a progressive ratio of purchasing power to prices. The so-called industrial and transportation trusts, the banking rings and investment pools, the labor unions and cooperative societies, and the associations of commission men and retail merchants are simply concerned in seeking to acquire the advantages of exclusion and organization. In each instance, united action for the elimination of waste and competition is the initial motive. "Cooperative efficiency in production" is the shibboleth of industrial organization; but one seldom fails to observe the tendency to a gradual metamorphosis of suc-

cessful "cooperation" into monopoly, and the simultaneous exchange of the ideal of *efficiency in production* for the slogan of *ability in acquisition.*

Economically considered, America has, until recently, been thoroughly democratic; that is to say, despite tendencies to social class and caste, the population has shared without essential discrimination in industry and production. But in late years possessors of the great fortunes which have been in the building for a half-century have begun seriously to devote themselves to leisure. In so doing, they have not only subtracted their own energies from the productive forces of the country, but they have increased their sumptuary demands and have alienated a host of laborers and a vast capital from the production of the necessities and comforts of plain living in order that a few may indulge an epicurean taste for the costly objects of vain and selfish desire. This tendency to luxury is leading students of market and industrial conditions to characterize the high bidding of wealthy and profligate spenders and of their improvident imitators as a significant cause of high prices; but a deeper analysis reveals the more vital phenomenon of *intensified social costs* attendant upon a relative reduction of the effective labor power of society and the subversion of a considerable part of the nation's capital. In this very dynamic aspect of modern life, one observes a tremendous increase in demand for the costly and enervating indulgencies of conspicuous expenditure and a more than proportionate decrease in the productive powers which contribute to the synchronous supply of the staples of life. Here, indeed, resides a fundamental problem in *national cost accounting.* The passing of the millionaire captains of exploitation and industry is imminent, and there is no more disconcerting contingency in the nation's future than the probable succession of a less hardy and energetic generation to their proprietary trusteeship of the country's wealth.

Price changes, which may be traced to an increased gold supply and the consequent depreciation of the dollar, react upon the cost of living only as certain reciprocal advantages and disadvantages are shifted among persons whose money incomes rest upon actual or implied contractural relations extending over the period of price change. For this reason, advancing prices are peculiarly advantageous to the debtor class, composed mainly of bonded business corporations, virtually discounting their obligations at an annual rate commensurate with the increase in prices. It is likewise obvious that expected returns to creditors and investors on securities bearing *fixed rates* of income are proportionately reduced. Wage earners and salaried persons are subject to a like disadvantage. Wage and salary scales are not readily readjusted and, especially, in their upward movements, show a considerable "lag" behind prices. Because of the prevalence of a customary

charge for many forms of professional service, such professions as medicine, dentistry and law may fail to command an increase in income sufficient to keep pace with advancing prices.

To avoid the popular error of attributing an increased cost of living to all persons under a régime of rising prices, and to reveal the actual effect of prices on costs, it is necessary to determine whether the majority of the population is included among those whose incomes have failed to respond to advanced charges or among the beneficiaries of high prices.

In the less fortunate class, which undoubtedly carries an increased burden of living costs, may be enumerated the following: (1) investors in fixed-income securities such as mortgages, bonds and life insurance; (2) unorganized wage earners; (3) salaried persons; (4) members of most professions; (5) proprietors of small-scale industrial and commercial enterprises; (6) middle-men and tradesmen not sufficiently organized to advance and maintain their charges coextensively with price movements.

In the more fortunate class, whose incomes bear a progressive ratio to prices and whose cost changes are, therefore, inversely proportional to price movements, we may expect to find: (1) proprietors of mortgaged and bond-issuing commercial and industrial enterprises; (2) proprietors of highly capitalized and centralized industries not subject to public control; (3) employers of unorganized labor and salaried persons; (4) members of highly organized trades and occupations; (5) grantees of public-service privileges whose net earnings support an advance in "franchise values" during the period; (6) proprietors of natural resources and recipients of tariff protection so circumstanced as to advance prices at will through a monopolistic control of supply.

There is an intermediate zone of economic condition which is practically free from the characteristic attributes described above. This neutral condition may be attributed to those whose incomes and expenditures are alike correlated with current prices, and is doubtless realized by a much larger proportion of the population than may at first appear. Many persons are so identified in their business interests with both characteristic groups as to realize no net change as a result of the advantage of either. Moreover, in so far as business is subject to competitive self-regulation and to reasonable official regulation, there may be a wearing away of economic inequalities of changing prices and a constant recruiting to the normal average of welfare.

The chief consideration involved in the question of prices and the cost of living is not the numerical measure of price changes nor the aggregate number of persons affected thereby; but rather the changing incidence of the burdens of life upon individuals and classes, and the logical results of disturbed economic stress upon the social structure.

A BUGBEAR OF REFORMERS

By Professor T. N. CARVER
HARVARD UNIVERSITY

TO the commonly accepted belief that water tends to flow down hill, a certain type of visionary would object that though such a statement might be true as an abstract principle, dissociated from the real world of human achievement, yet it is not true as a matter of actual economic fact because men have invented pumps and pipes which make water flow up hill. His position would then be precisely like that of Professor Miller in his recent attack upon the law of diminishing returns.[1] His argument is, briefly, that improvements in productive processes, combined with increasing accumulations of capital, may and do enable us to get larger products than formerly, in spite of what is generally called the law of diminishing returns. If our supposed visonary were asked why pumps and pipes were necessary, he could only answer: because water tends to flow down hill. Similarly, if Professor Miller were asked why inventions and improvements in production were necessary in order to enable increasing populations to maintain their standard of living, his only reply, did he not dodge the question, would be: because of the law of diminishing returns.

Professor Miller further suggests that the law of diminishing returns "closes the door of hope" because "hopelessness is inherent in a world of diminishing returns." Now the law of diminishing returns closes the door of hope only in the sense that gravitation closes it, and hopelessness is no more inherent in a world of diminishing returns than it is in a world of gravitation. Gravitation has closed the door of hope to many a visionary inventor who could not get his device to work because of the stubbornness of this law, but it has not closed the door to those who took it into account and adjusted their plans to it. Gravitation doubtless closed the door of hope to Darius Green, but not to the Wright brothers. Similarly, the law of diminishing returns, and its companion, the law of population, most effectually close the door of hope to the Darius Greens of economic reform, but not to those reformers who take these laws into account and plan in conformity with them.

Even though, as Professor Miller remarks, capital may take the place of land in a growing population, he overlooks one rather important fact, namely, that this substitution of capital for land on a large scale is the accompaniment of a change from agriculture to manufacturing and

[1] See The Popular Science Monthly, for December, 1911.

commerce, and that it applies only within certain limited territories and does not materially affect the problem if we consider the world at large. Because several million people happen to make a living on Manhattan Island by substituting capital for land, it does not follow that the whole world could do the same, nor would it follow even if two hundred million people could make a living in a similar way within the present boundaries of the United States. Our country would not then be truly self-supporting, in any large and complete sense, any more than the Island of Manhattan, or the Island of Great Britain, or Belgium now is. All urbanized populations bring in the products of the soil from regions where soil is abundant, work them over in industries which require much labor and little land, and send them out again to exchange for raw materials, living all the while on the profits of this class of transactions. As these urbanized populations grow, it is necessary to send farther and farther, to wider and wider fields for the products of the soil. Why is this necessary? Why should not England get all her agricultural products from her own area? Merely because of the law of diminishing returns. To double the produce of the English farms would not double, but treble or quadruple, the cost of cultivation. That is what the law of diminishing returns means, and it never meant anything else. Because of this law England finds it cheaper to send to distant countries for her wheat and beef, paying the cost of transportation, than to cultivate her own farms with a sufficiently high degree of intensity to enable her to live off her own soil.

To be sure, the available waste land of the world is not all in use yet, and our increasing urban populations will be able, for many years to come, to thrust their transportation systems out farther and farther in order to secure these products which require land—space—superficial area for their efficient production. Therefore we need not worry about the food supply for a long time to come. It may, however, surprise some of our urban economists to learn how little modern science has enabled us to economize land, our inventions and machines having in the main, increased the product per unit of labor rather than the product per unit of land. So little has it increased the latter that, taking into account the rise in the standard of living, it is probable that it takes as much land to support the average family in any part of the civilized world to-day as it did when Malthus wrote his epoch-making work on population. By support I mean support in a complete economic sense. I mean that it probably takes as much land to supply all the things actually consumed by the average family to-day as it did then.

We could, to be sure, if we chose to do so, consume more of those crops which respond to intensive culture, such as corn, potatoes, bananas, etc., and less of those which yield their best results under ex-

tensive culture, such as wheat, beef, etc. This would mean a change in the standard of living. Possibly it might be a good thing to make this change in our habits; but why should it be necessary? Simply because of the law of diminishing returns. That is to say, in order that increasing populations may have plentiful supplies of bread and beef *from the same areas,* these crops would have to be cultivated more and more intensively. These crops do not respond readily to this method, and the cost per unit rises very rapidly, which, again, is due to the law of diminishing returns. Other crops respond somewhat better, but they also come under the same law, and eventually the point would be reached when more land would be better than less land, even for the growing of these crops. Wherever that is true, the point of diminishing returns has been reached. Wherever agricultural populations tend to spread as they are doing out west to-day, rather than to concentrate, it is a sign either of general insanity on their part, or of diminishing returns from land. I am one of those who believe that it is a sign of diminishing returns, that is, that these increasing populations find it more advantageous to spread over more land than to concentrate on the land already in their possession and try to get their living from those limited areas. That, again, means diminishing returns. Increasing the number of men working on a given area of agricultural land will not proportionally increase the products. That means a smaller product per man, though it may mean a larger product per acre.

The law of diminishing returns as ordinarily stated is, really, nothing more than a technically specialized statement of the fact that land is a limiting factor in production. A limiting factor is merely a factor upon whose quantity depends, in some degree, the quantity of the product. Wherever it is true that more land is better than less land, or where one can say, "more land more product, less land less product," there land is a limiting factor and the law of diminishing returns is in operation. From a narrow and piecemeal view, it sometimes appears that a manufacturing and commercial policy frees a nation from this limitation, because, so long as an abundance of raw materials can be brought in from the outside, and all the finished products of the manufacturing industries can be marketed somewhere else, there seems to be no assignable limit to the amount which a nation can manufacture, if it only have labor and capital enough. That is to say, there always seems to be room enough for manufacturing and business sites. Land, from the national point of view, does not seem to be a limiting factor in these industries, though occasionally, in the narrower limits of a single city, land becomes scarce even for these purposes. But, as suggested above, this is a piecemeal view of the problem, for economic laws and principles are no more confined within national boundaries than they are within city walls. If all the industries, both rural and

urban, which are necessary for the full economic support of a self-sufficing population are considered without respect to national or municipal boundaries, it will be found that land is, in all civilized countries, a real limiting factor of production, which is the same as saying that the law of diminishing returns is everywhere in operaton where these conditions are considered.

Is there any occasion for alarm in this situation? Certainly not for us in the immediate future. From a scientific point of view, however, there are two things which ought to be said. In the first place, time is an element which may be left out of account. Whether the difficulties inherent in this situation will become acute in a hundred, a thousand or a million years, is not a matter of such importance as the question, are these difficulties inherent? In the second place, while we may not have any immediate cause for alarm, certain other people have, though that may not be our concern. The people of western Europe may not have had any cause for alarm in the days of Malthus, for the whole American continent lay before them. But the American Indians had ample cause for alarm had they understood the situation. Similarly, the civilized races of to-day may be at ease in Zion, their temporal salvation being assured, since South America and Africa lie open before them. But certain other races already in possession of those alluring Canaans may well be on the anxious seat, for their temporal damnation is imminent. It will be so easy for us to take these lands that, doubtless, it would be very foolish for us to worry about the land question. Fortunately, we are not the people who have to do the worrying, and doubtless a merciful providence has rendered the people who ought to worry incapable of seeing anything to worry about.

Since our growing agricultural population is showing a tendency, as all agricultural populations of the occident have shown for thousands of years, to spread rather than to remain pent up in their national boundaries, one of three things must happen if our population should continue to increase: (1) We must become more and more a manufacturing and commercial people, depending more and more upon the outside world for our agricultural produce, and joining in the general scramble of the commercial nations for outside markets; (2) we must restrain our people at home by force to prevent their emigration until the pressure of population upon subsistence becomes strong enough to check further increase and restore an equilibrium; or, (3) our people will spread over the territories occupied by inferior races, dispossessing them of their lands and sending them the way the Tasmanians have gone and the American Indians are going. Why are we compelled to face these alternatives? For no reason in the world except the law of diminishing returns, which, by the way, is reason enough.

RESEARCH IN MEDICINE[1]

By Professor RICHARD M. PEARCE
UNIVERSITY OF PENNSYLVANIA

I. Antiquity to 1800; The Efforts of Isolated Investigators

THE phrase "Research in Medicine" will naturally arouse different thoughts and associations in the minds of different groups of men.

The bacteriologist will be reminded of Pasteur, Koch, Behring and Flexner and the triumphs of bacteriology and serum-therapy; the surgeon, of Lister and antisepsis, of anesthesia, and of the X-ray; the physician of new means of cure and of diagnosis, of specific sera and vaccines, of the electrocardiograph, the polygraph and other complicated instruments of precision; and the average layman of a confused and confusing welter of catchwords and slogans for popular agitations vaguely associated with antitoxins, mosquitoes, good water supply, sewage disposal, lowered infant mortality and the modern treatment of tuberculosis. But in the last analysis the impressions of all would be of progress in a period representing a little more than half of the past century. This period is indeed the golden age of medical progress and one to which the historian or philosopher must give his best attention if he is to interpret, properly, the impulses which actuate medical research at the present time. That the earlier history of medicine is overshadowed by the rapid progress of modern discovery as represented in bacteriology is in the nature of things. But it should not, for that reason, be forgotten that the art of medicine existed before this period and with it much science. The pathologist, on second thought, reminds us of Morgagni and Rokitansky and the beginnings of pathological anatomy; the physiologist recalls Harvey and Haller; the surgeon mentions Ambroise Paré; the anatomist, after recalling many worthies, takes us back to Vesalius, to Galen and finally leaves us as does the internist, with Hippocrates, 400 years before Christ.

With this stretch of time and with these widely varying aspects of endeavor one must deal in attempting to present the story of research in medicine. It would be comparatively simple to chronicle the advance in any one field, as, for example, surgery, pathology or therapy; but this would, I fear, be less interesting and certainly not enlighten-

[1] These lectures were given as the annual Hitchcock lectures at the University of California. The foundation was created by Mr. Charles M. Hitchcock, who bequeathed to the University of California an endowment, the income of which was to be devoted to "free lectures upon scientific and practical subjects, but not for the advantage of any religious sect nor upon political subjects."

ing as to the full influence of research. The advantages to the community resulting from research in medicine are advantages because research has done away with conditions which were disadvantageous to the health, the happiness and prosperity of the community—in short such research has removed the impediments to a higher, happier and more prosperous civilization. It is necessary, therefore, in order to emphasize the importance of what has been accomplished, to portray the conditions of community life and individual hygiene, of medical practise and medical thought, and of science and philosophy at such periods as immediately precede definite advances in medical knowledge. The first of these lectures, then, bringing the story down to the beginning of the nineteenth century, will be presented from this point of view. The second lecture devoted to the influence of physics and chemistry, and the third to the rise of bacteriology, will outline the development of laboratory methods of investigation, the story, essentially, of medicine in the last half of the nineteenth century. The fourth lecture will be a survey of present-day methods and problems, and the fifth lecture will be a discussion of the position of medical research in America, its facilities, needs and opportunities, with special reference to medical research as a function of the university.

Of medicine in the earliest stages of its development we have no knowledge. Not until we arrive at a period of civilization as highly developed as that of the Assyrians and Egyptians do we find references to the practise—the studied practise—of medicine as a healing art. For all that precedes that period we must rely on analogy with medical practises among the aboriginal races to-day. But we can, nevertheless, safely assume that the healing art in all times, no matter how simple its form, was the practise of methods having for their object the relief of pain or the repair of injuries caused by mechanical means. Such methods must have been, at first, instinctive and empiric, or the result of chance observation. Some may, indeed, have been analogous to the methods which an animal adopts to cleanse a wound or protect an injured limb. The use of irritants, of emollients and of scarification, the binding of wounds, the mechanical support of a fracture and assistance in childbirth are primitive practises doubtless resulting from chance observation or experience. It is readily conceivable that the use of stone tools and weapons in hunting and in war may have originated the idea of intervention by operation; and that surgical dexterity may have increased proportionately to the improvement of weapons in the bronze age. Likewise it must be assumed that chance experience led to a knowledge of the action of the vegetable and mineral substances of the early materia medica. But of these beginnings we have no historical knowledge.

Our first authentic knowledge of medicine, fragmentary though it

is, is obtained from the cuneiform inscriptions which record the Babylonic-Assyrian civilization. These records are of a medicine controlled by the priesthood, closely linked to astrology and characterized by a belief in the influence of metaphysical forces, gods and demons. They do, however, contain references to the use of the knife in surgery, the healing of fractures and the internal administration of herbs, but all essential therapy is obscured by mysticism, ritual observances and magical formula. From the point of view of diagnosis, it is of interest that these records refer to the inspection of the urine and blood and to the collection of a series of observations upon disease, what we would now call the "clinical history" or record of a patient. These, however, were taken, not as to-day to aid in the diagnosis, but had the value of omens to aid the priest in his prophecy as to the outcome of the illness, or as we would say to aid prognosis. Such records were of little value, for without a knowledge of pathology—that is, of the underlying anatomical changes responsible for the symptoms—they were on the same level as astrological speculation and the interpretation of dreams. Inferences were not drawn from the empirical facts of clinical observations, but all observations were interpreted in the light of the supernatural, the ritualistic and the magical. This veil we find over all ancient medicine.

Egyptian medicine of a period 2,000 B.C. was much the same as the Assyrian, but the priestly science, as taught in the schools of the temples, developed a considerable knowledge of botany and zoology, without, however, an insight into the structure and functions of the human body. An extensive materia medica allowed the use of medicines as draughts, electuaries, gargles, snuffs, inhalations, salves, plasters, poultices, injections, suppositories, enemata and fumigations. As to general surgery, there is no evidence, aside from circumcision and castration, of operations other than those for the removal of surface tumors. Yet ophthalmology, otology and dentistry were known and practised as specialties. Obstetrics, on the other hand, does not appear to have been of interest to the physician. The hygiene of the Egyptians ranked higher than their therapeutics and included definite rules concerning meat inspection, bathing, clothing, diet, care of the dwelling and of infants. Indeed there is much ground for the belief that much of our modern hygiene can be traced back through Greek and Hebrew to the pioneer work of the ancient Egyptians.

Persian medicine is of little moment and differs but slightly from that of other ancient peoples in its religious-hygienic measures. One phase of religious belief was disastrous for the development of even simple empiricism—the belief that the dead and the diseased were unclean. Such a view naturally made impossible the study of anatomy and diagnosis. The sick, as unclean, were isolated, washed and purified

—a procedure which in our time we associate with good hygiene and the care of those suffering with contagious diseases; with the Persians, however, it was purely a religious form based on a belief in demons.

After the priestly hygiene of the Egyptians and Persians comes naturally, and probably sequentially, the social hygiene of the Old Testament. I need only remind you of the Mosaic laws, rational even in the light of modern science.

From the literature of antiquity much else might be cited to show the state of medicine among ancient peoples, the influence of religion, of primitive superstition and mysticism, all of which, however well-intentioned, prevented or obscured exact observation and deduction. The development of knowledge by observation and critical argument came slowly, and was possible only when the priest was no longer the physician. This great advance we associate with the period of Greek civilization and the name of Hippocrates.

Hippocrates may be considered in many ways, as physician, surgeon, philosopher and medical historian, but to one interested in the beginnings of research in medicine he is of importance as the first to record results based on observation, experiment and deduction, the tripod of the method of science. As a result, although much of his theory has been discarded, many of his procedures based on exact observation still stand the test of time and in many instances form the basis of modern methods. His age (470–361 B.C.) was the age of Pericles; contemporary with him, Thucydides wrote history, Phidias carved statues, Democritus originated his atomistic theory of the universe, and Socrates talked "human affairs" and "practical reason." That these men were real to one another is shown by the fact that Hippocrates was requested to declare Democritus insane and that Pericles died (429 B.C.) of the great plague which Hippocrates attempted to combat.

From this correlation of names it is evident that medicine shared in the general growth of Greek culture, and there is every evidence that Hippocrates was as great a representative of Greek intellect as were his contemporaries. Greece was at the height of its brilliant progress; it was, for the time being, the political, commercial, intellectual, scientific and artistic center of the universe. But among the Greeks the priests were not, fortunately for medicine, political or intellectual leaders; leadership was possessed first by the poets and later by the philosophers, and, under such circumstances, Greek medicine, freed of religious influence and fostered by philosophy, took a substantial form, and, though it contained much of generalized speculation, it had the solid foundation of unbiased observation. The former has perished under the influence of time and progress; the latter, resting on actual experience and genuine biological knowledge, remains. Of the methods of Hippocrates some idea may be obtained from the fact that he is

responsible for the very term "hypothesis," which, in its scientific application, he invented.

Some of the experiments of the Hippocratic schools may be considered as the first in the field of experimental physiology, as for example, the feeding at the same time of different kinds of food and the study, after induced vomiting, of the stage of digestion of each. It is, however, in the field of clinical observation that Hippocrates excelled. His inferences were frequently wrong, but his descriptions of the symptoms of a disease, as an aid to diagnosis and prognosis, were at once picturesque and accurate. How accurate and vivid they were may be seen from the fact that the characteristic signs of impending death are still known as the "facies Hippocrates." This exercise of minute observation and accurate interpretation of every symptom—the method of clinical medicine—which has influenced medicine in all succeeding ages, was the beginning of the study of what we now term the "natural history of disease." In therapy Hippocrates recognized the natural tendency to health (*vis medicatrix naturæ*) and this principle influenced all his therapeutic efforts. In addition to this substantial service to medicine we owe him certain idealistic influences as shown in the Hippocratic oath and in his constant desire to place all knowledge freely and fully before the profession at large.

Certainly medicine under Hippocrates, as contrasted with that of the preceding ages, was magnificent, and it is not surprising that after his death, he was deified. To us he represents the beginnings of an exact medicine, and his influence is seen in many of the theories, methods and ideals of modern practise. Hippocratic medicine, Hippocratic doctrine, Hippocratic oath, are current phrases, and the admonition "Back to Hippocrates" is an admonition to beware of theory and seek the solid ground of observation and experiment.

Between Hippocrates and Galen lie nearly five hundred years without progress in medicine, except as the brilliant Alexandrian school, sheltering Euclid, Archimedes and Ptolemy developed, under Herophilus and Erasistratus, a school of anatomy (ca. 300 B.C.) which established many new anatomical facts. But as Neuburger states in his discussion of early medical theories, "Collection and observation of facts constitute the first step in science, but not science itself." The observation of anatomical facts during these centuries is naturally of some importance in connection with the growth of anatomy, but unfortunately of no importance as regards the influence of those facts on medical theory, for physiology remained a field for speculation while the facts gained from anatomy were used only to strengthen the older speculation and dogmatism, and to rehabilitate discarded doctrines. To the Alexandrian school and to Galen, however, must be given the credit of a careful study of anatomy by dissection, and this honor is the

more deserved because, from Galen to Vesalius—a stretch of nearly fourteen hundred years—knowledge of anatomy was not advanced.

Galen (131–201 A.D.), a Greek, working in Rome, followed the traditions of the Alexandrian school in which he had been educated. He dissected freely a variety of animals, including, it is recorded, an elephant. It is, however, as an experimental physiologist that he brought new light to medicine. He supported the statements of the Alexandrian school, that nerves had motor and sensory functions, elaborated the theory of the control of muscles by nerves, and of the brain as the center of the nervous system, and, more important still, supported these convictions by well-planned ingenious experiments. His experiments on the brain and cord constitute the first experimental study of the cause of paralysis, and he thereby became cognizant of the fact that injury to one side of the brain affects the opposite side of the body. He established, again by experiment, that urine is secreted by the kidneys, and propounded the theory that the blood goes to the kidneys in order that the watery part may be filtered off. He studied the heart and its movements, recognized the fetal nature of the foramen ovale and the ductus arteriosus, wrote of aneurysm and practised the ligation of arteries.

Galen is the link between Hippocrates and Alexandrian anatomy, on the one hand, and Vesalius and Harvey, on the other.

> With his death and the passing of his immediate successors progress languished and expired, for the ancient world was dying and was bearing down with it the humaner arts. . . . For generations it seemed that the church alone had survived . . . cherishing ignorantly often, but jealously and fiercely, the records of a past science. (Mumford.)

The intellectual world of Rome, Alexandria and Constantinople was busied with theological controversies. The church became the arbiter of all knowledge and demanded that all science must conform to the Scriptures. Moral and intellectual progress became impossible. The political world survived the invasion of the barbarians, but the intellectual world was dying of dogma. For hundreds of years it was "first the soldier; second the priest; third the lawyer; fourth the merchant; fifth the physician; and then after a long interval the surgeon, ranking with the humblest of craftsmen." (Mumford.)

Nearly fourteen centuries pass after Galen before we can again take up the thread of progress. In these centuries—lost to science generally—the history of medicine shows but one isolated period of effort worthy of mention. This is that period represented by the Arabian school founded after the Mahommedan conquest and at its best from the ninth to twelfth centuries. This school represents no progress in anatomy, physiology or the general theory of medicine (which is to be explained by the fact that the religion of the Mussulman considers contact with a corpse sacrilege and thus debars dissection), but the

Arabs had an insight into chemistry, and, though they pursued their researches in the interests of alchemy and in the hope of finding the "elixir of life" or means of transmuting metals, they made, nevertheless, valuable chemical discoveries and in this way aided the art of pharmacy.

We therefore enter the sixteenth century of the christian era with little or nothing added during 2,000 years to Hippocrates's methods of exact observation in clinical medicine and surgery, with no decisive contribution to anatomy or experimental physiology for 1,300 years and with the beginnings of chemistry as applied to medicine and pharmacy removed by 600 years.

But despite this absence of real progress, a thin thread of learning and practise connected the medicine of Galen with the dawn of science in the middle ages. This is evident in the story of medicine in the monasteries and in the schools at Salerno and Montpellier in the twelfth century, but it is a medicine of the Roman period tinctured with magic and superstition and with no advance in theory or practise and certainly no increase in science.

The medicine associated with the revival of learning had its beginnings in the translation of Greek treatises on medicine through the Arabic; and in the early universities, especially those of Padua and Bologna and this revival of the exact methods of Hippocrates and Galen, gave to medicine a basis more substantial than the traditions of monastic medicine which had been perpetuated through ten centuries, and upon which were founded those widely scattered, but epoch-making advances which medicine reckons as its share in the general revival of literature, art and the sciences. With the name of Luther, Michael Angelo, Raphael, Titian, Copernicus, Columbus and Galileo we place those of Vesalius, Paré and Harvey. These names represent the period of the Renaissance, to which we look back with pride and satisfaction, but seldom with a thought of the conditions of home and community life. We are concerned usually with its deeds and achievements rather than with its social and hygiene conditions. But it is to the latter that I wish here briefly to direct attention.

The homes and habits of the people were filthy. As late as the sixteenth century in England, the streets of the populous cities were paved with straw and rushes, which soon broke up into powdered dust. Householders swept the filth of their apartments into the streets, and threw garbage there also, where, with the ground of rush and straw, a most intolerably filthy condition was produced, which rain modified, but did not remove. Moreover, people seldom bathed their bodies or washed their clothes. Besides, the food they ate contributed to disease. They lived chiefly on salt fish and flesh, with a modicum of stale vegetables. The domestic animals, the source of their meat, were herded in enclosures of the worst imaginable filth. Mutton was the chief flesh food of the people, but their flocks in cold season were herded in basements, partly underground, places without light and air except such as gained admittance from the door. Milch cows

were confined to these places also. The source of the food supply was, therefore, foul. . . . Places of public resort were without means of ventilation. The air of the churches was death-dealing, and made tolerable only by the fumes of incense. (Gorton.) Personal cleanliness was unknown; great officers of state, even dignitaries as high as the Archbishop of Canterbury, swarmed with vermin; such it is related was the condition of Thomas a' Becket, the antagonist of an English king. To conceal personal impurity, perfumes were necessarily and profusely used. The citizen clothed himself in leather, a garment, which, with its ever-accumulating impurity, might last for many years. . . . After night-fall the chamber shutters were thrown open, and slops unceremoniously emptied down. (Draper.)[1]

From the fourteenth to the sixteenth century plagues were frequent and attended with great mortality. Among the plagues known by various names as the "sweating sickness," "black death," etc., we are able to distinguish bubonic plague, typhus and small-pox. Likewise syphilis had been on the increase since the fifteenth century, and pre-

[1] The original upon which these statements are based I have been unable to obtain. Gorton's statement is evidently at second hand. C. Creighton in his "History of Epidemics in Great Britain" doubts the accuracy of the sweeping charges "of neglect of public hygiene" and "of lack of rudimentary instincts of cleanliness" in Plantagenet and Tudor times, but as careful a writer as F. Harrison gives in "The Meaning of History" the following summary of personal and community hygiene in the Middle Ages:

"The old Greek and Roman religion of external cleanness was turned into a sin. The outward and visible sign of sanctity now was to be unclean. No one was clean; but the devout Christian was unutterably foul. The tone of the Middle Ages in the matter of dirt was a form of mental disease. Cooped up in castles and walled cities, with narrow courts and sunless alleys, they would pass day and night in the same clothes, within the same airless, gloomy, windowless and pestiferous chambers; they would go to bed without night clothes, and sleep under uncleansed sheep-skins and frieze rugs; they would wear the same leather, fur and woolen garments for a lifetime, and even for successive generations; they ate their meals without forks, and covered up the orts with rushes; they flung their refuse out of the window into the street or piled it up in the back-yard; the streets were narrow, unpaved, crooked lanes through which, under the very palace turrets, men and beasts tramped knee-deep in noisome mire. This was at intervals varied with fetid rivulets and open cesspools; every church was crammed with rotting corpses and surrounded with graveyards, sodden with cadaveric liquids, and strewn with disinterred bones. Round these charnel houses and pestiferous churches were piled old decaying wooden houses, their sole air being these deadly exhalations, and their sole water supply being these polluted streams or wells dug in this reeking soil. Even in the palaces and castles of the rich the same bestial habits prevailed. Prisoners rotted in noisome dungeons under the banqueting hall; corpses were buried under the floor of the private chapel; scores of soldiers and attendants slept in gangs for months together in the same hall or guard-room where they ate and drank, played and fought. It is one of those problems which still remain for historians to solve—how the race ever survived the insanitary conditions of the Middle Ages, and still more how it was ever continued—what was the normal death-rate and the normal birth-rate of cities? The towns were no doubt maintained by immigration, and the rural labourer had the best chance of life, if he could manage to escape death by violence or famine."

sented a peculiar malignancy, and, like small-pox, attacked high and low alike. The causes and origin of these plagues are not difficult to find. Except for the Cloaca Maxima at Rome not a sewer of any consequence existed in Europe; drainage was inadequate, the streets were unpaved, and public baths or other facilities for bathing were unknown. Of sanitation no knowledge was at hand. The dead, including the victims of various plagues, were buried hastily—instead of being burned—and usually in shallow ditches, thus allowing presumably an easy pollution of water supplies. As to this, under ordinary circumstances no precautions were taken to keep the water supplies free from fecal and other contaminations. Doubtless, taxes on bread and window panes were responsible in no small part for that diminished resistance which invites infection. Against the spread of plagues the physicians were helpless. The College of Physicians at Paris in the fifteenth century at the time of the "sweating plague," were, after mature consideration, "of the opinion, that the constellations, with the aid of nature, strive, by virtue of their divine might, to protect and heal the human race." This state of mind does not seem so surprising when we recall that Roger Bacon, "the truest philosopher of the Middle Ages," still sought, in the thirteenth century, the philosopher's stone and the elixir of life. "The Royal Touch" was still a favorite cure for scrofula ("The Kings of Evil") and various other ills, and indeed persisted into the time of Queen Elizabeth. From "The Anatomy of Melancholy" (1621) we have it that "there be many mountebanks, quacksalves and empiricks, in every street almost, and in every village."

> Shall we, then, wonder that, in the famine of 1030, human flesh was cooked and sold; or that, in that of 1258, fifteen thousand persons died of hunger in London? Shall we wonder that, in some of the invasions of the plague, the deaths were so frightfully numerous that the living could hardly bury the dead? By that of 1348, which came from the east along the lines of commercial travel and spread all over Europe, one third of the population of France was destroyed. (Draper.)

Also, the condition of the insane was pitiable; until well into the eighteenth century they were imprisoned, chained and treated as wild beasts.

Rational therapy did not exist, though it is interesting to note that several important empiric specifics came gradually into general use, as mercury and sulphur introduced in 1510 by Paracelsus, sometimes termed "charlatan and bombast"; after Harvey's time, Dover's powder (*Pulvis Ipecacuanhæ* Comp.) through Captain Dover, physician and buccaneer; and *Cinchona* (quinine) through the Countess of Cinchon, wife of the Viceroy of Peru, who brought it to the attention (1638) of the Jesuit priests, hence the name, Jesuit's bark. Truly, empirical therapy made progress by curious routes.

Civil surgery was in a chaotic state, the barber surgeon contended

with the surgeon proper or "surgeon of the long robe" in the fields of minor surgery and both ranked far below the physician. In fact, surgery was largely abandoned to a class of ignorant barbers, bathers and bone-setters. Many operators were itinerant, going from city to city and frequently limiting their work to one or two kinds of operation, as that for cataract, or stone, or hernia. Military surgery without anesthesia or antisepsis was a horror of rough and ready emergency operations with boiling oil or heated iron as styptic and cautery, a torture beyond imagination. Indeed, to get an idea of the horrors of surgery in the lazaretto of the battle field even down to the year 1812, the date of Napoleon's descent upon Moscow, one needs but to read Tolstoy's work "War and Peace."

Thus we find the stage set for Vesalius and Paré, who with Hunter, though he entered somewhat later, laid the foundation, which, when anesthesia and antisepsis were added in the nineteenth century, gave surgery its right to claim a scientific basis. Vesalius, occupying a chair of surgery at Padua, developed anatomy as an exact observational science; indeed he may be considered as the founder of modern anatomical research. This was his great work; this and his influence in weakening the old speculative medicine and in establishing the principles of the scientific method. It was not an immediate influence, for upon the publication (1543) of his Fabrica Humani Corporis "the wrath of intrenched conservatism descended upon him" and he was forced to leave Padua, but his work was not in vain, for it hastened the development of surgical science and gave to anatomy the impetus necessary for its development as an observational science.

Ambroise Paré (1510–1590) began life as an humble barber-surgeon, and ended as the greatest surgical authority of Europe and the best loved man in France. (Mumford.)

Why the greatest authority? Because he went through the world with his eyes open. Why the best beloved? Because of his own unaided efforts he did away with more actual pain than has perhaps any other single individual except the discoverer of anesthesia. His methods were those of the practical clinician—observation as the basis of deduction unhampered by tradition. The story is told that Paré in his first military campaign followed the old custom which prescribed the use of boiling oil for all wounds. But after one severe engagement the oil gave out and he used, fearful of the consequences, a simple ointment. To his surprise he found that the wounds so treated healed more rapidly than under the old treatment. On this basis of simple observation and sound reasoning, he combated, against great opposition, the old treatment and established simple rules for the care of wounds. So also was it with the ligation of vessels after amputation. The custom had been to cauterize with the red-hot iron, the effect of which both physically and mentally it is not difficult to imagine. Paré reasoned

that as ligation of veins and arteries in simple wounds was possible, it was possible also at amputation, and at the first opportunity he demonstrated the correctness of his views. So by doing away with boiling oil and the heated iron he ranks among the greatest of humanitarians and, by establishing rational procedures for the treatment of wounds and for the ligation of vessels, as one of the greatest of surgeons.

Here it is well to depart from the chronological order and discuss John Hunter and his work and thus bring the advance in surgery to the year 1800. Between Paré and Hunter surgery was influenced by Haller and Harvey, but both these must be treated in detail in a consideration of other lines of activity. Suffice it to point out here that Harvey's work on the circulation of the blood and Malpighi's discovery of capillary circulation advanced surgery enormously by clearing up for the surgeon the mysteries of the blood-vascular system. The dread of hemorrhage had previously deterred surgeons from all operations except those of dire necessity or those in which the operation was in a gangrenous tissue. With this mystery of hemorrhage solved, the surgeon boldly ventured into new territory and rapidly extended the possibilities of his art.

John Hunter, pathologist, physiologist and surgeon, was active in the latter part of the eighteenth century. He worked in anatomy, comparative anatomy, physiology and surgery; essentially a laboratory investigator, "content" it is said "with four hours of sleep, scanty rations and little play." (Mumford.) Many were his contributions to anatomy, but his work on coagulation of the blood, inflammation and the repair of wounds, and, above all, the demonstration, that after ligation of vessels there occurs the establishment of a collateral circulation by anastomosis, were of the utmost importance to surgery. This latter, the basis of his famous operation for aneurism, was the result of a study of the growth of deer's antlers, in the course of which he tied one of the carotid arteries. To his surprise the cold antler of the ligated side, after two weeks, became warm. Dissection demonstrated that the ligature had not slipped, and on the basis of this observation he established those principles concerning the ligation of vessels in continuity so important in modern surgery. He also presented the first satisfactory explanation of inflammatory and thrombotic diseases of veins and contributed to the knowledge of gunshot wounds and of many other phases of medical science; but his great influence was the impetus which he gave to proper scientific research in medicine as well as surgery, in pathology as well as physiology.

To Hunter, the nineteenth century English school of surgery owes its fame, and in his honor the Royal College of Surgeons established the annual Hunterian Oration. After Hunter, and largely due to his influence, surgery advanced surely, though slowly, but without momen-

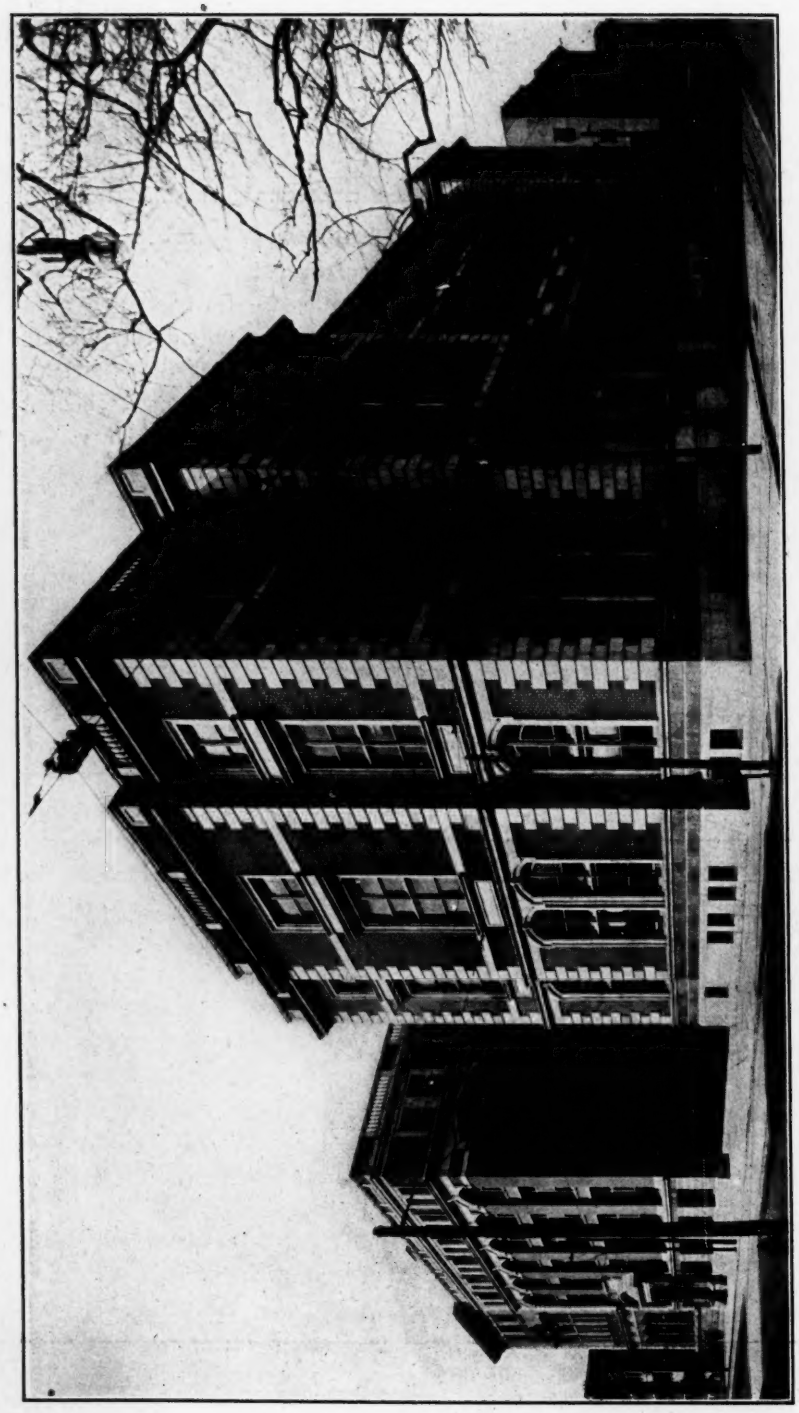
tous discoveries until the advent of anesthesia and asepsis in the middle of the nineteenth century. We may therefore leave surgery and turn to Harvey and events in physiology prior to 1800.

Harvey was of the Elizabethan period, a contemporary of Shakespeare, Milton, Dryden, Bacon, Descartes and Kepler. He studied at Cambridge and Padua and on his return to England, as Lumleian lecturer, gave most of his time to teaching and dissection. It was during the second year (1616) of such labors that he first propounded his theory of the circulation of the blood, but it was not until 1628 that his complete work on the subject was published. With the discussion as to the part played by his forerunners, by Servetus, Cæsalpinum and others in elucidating the mysteries of the circulation we are not now concerned. The honor of the establishment of the theory is Harvey's. More than this, it was the character of his exhaustive observations on a score of different animals (and on the heart of the chicken *in ovo*), his logical reasoning, and his convincing experiments that finally led to the correct solution and to the resurrection of a new method in medicine, that of experimental physiology. It may be remembered that Galen has been referred to as the first experimental physiologist; after fourteen hundred years he was followed by Harvey; then came Haller and Hunter, prophets of that modern experimental physiology which was in the nineteenth century to advance along all lines and to give to medicine a scientific foundation.

It is difficult to overestimate the significance of Harvey's discovery of the circulation of the blood. Sir Thomas Brown considered it greater than Columbus's discovery of America; Hunter ranked it with that of Columbus and that of Copernicus. Certainly it opened a new world in medicine. Progress, however, did not immediately follow Harvey's discovery, though four years after his death the capillary system, a link necessary to the completion of his doctrine of the circulation, was discovered by Malpighi. The period, was, however, one of detailed observation in anatomy, and despite the work of Malpighi and Borelli, experimental physiology languished until the time of Haller (1708–1777), who made additions to the knowledge of the mechanics of respiration, established the theory of irritability as a specific property of muscle and made important observations in embryology. How prophetic of the advances of the nineteenth century are the problems with which Haller and Hunter busied themselves. The study of the irritability of muscle suggests physiological instruments of precision, and embryology implies the compound microscope and the microtome, the familiar instruments of the latter nineteenth-century investigator in medicine. Hunter's problems—phlebitis, aneurism, syphilis, inflammation, the repair of wounds, the coagulation of the blood—remind one of many phases of present-day investigation. Prophetic also of the

phenomenal development of pathology, under Rokitansky and Virchow, was Morgagni's publication in 1761 of his "Seats and Causes of Disease," the first systematic effort to correlate clinical manifestations with pathological anatomy. Likewise, the introduction by Jenner (1796) of the systematic practise of vaccination against small-pox, presaged those methods of prophylaxis which within the next century were to revolutionize the methods of controlling many of the infectious diseases. We will return in later lectures to both Morgagni and Jenner and their influence on the development of pathology and immunology, but here they serve with Hunter and Haller to illustrate how a few individuals with a genius for accurate observation, sound thinking and exact experimentation may by their contributions foreshadow the activities of a succeeding century, and be the forerunners of new schools of thought. Their labors with those of Vesalius, Paré and Harvey are examples of that effort which, isolated though it was, during the three or four centuries preceding the year 1800 and proceeding as it did from individuals living and working in widely separated places, nevertheless, constituted in the sum a sound body of knowledge readily available to future investigators, equipped with new methods. With the exception of Paré no one of these men was thoroughly appreciated by his contemporaries. Vesalius was reviled and forced to leave Padua, Hunter's ligation of a vessel in continuity was at first ridiculed and Harvey's discovery, like others in various fields, because not possible at once of practical application, did not appeal to medical men who still clung to the traditional teachings of Galen. It was the period of genius working alone without the approval of the profession, without the support of universities and laboratories, and without the means of publications and the means of travel that to-day render almost immediately available new advances, achievements and theories. One had to journey to the city or country of this or that authority or investigator to get his views. Merz, in his "History of European Thought in the Nineteenth Century," gives, as examples of such voyages of discovery Voltaire's visit "to England in 1728, where he found the philosophy of Newton and Locke, at that time not known and therefore not properly appreciated in France; the journey of Adam Smith in 1765 to France, where he became acquainted with the economic system of Quesnay"; and the visit of "Wordsworth and Coleridge to Germany, whence the latter brought to England the new philosophy of Kant and Schelling." It is not surprising that under such circumstances advances in medicine, as in science generally, were few and far between.

How the change from individual to organized effort came about, and how medicine became the subject of investigation by scientific methods in laboratories established for that purpose will be shown in the next lecture.



THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

THE PROGRESS OF SCIENCE

THE CENTENARY OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

THE Academy of Natural Sciences of Philadelphia celebrated on March 19, 20 and 21 the centenary of its foundation, the last day being the actual date of the anniversary. On the first day Dr. S. G. Dixon, the president of the academy, gave a historical address and Dr. Edward J. Nolan, the secretary, gave reminiscences of the fifty years of his official connection with the academy. Delegates to the number of 147 presented letters, credentials and congratulations from the scientific and educational institutions which they represented. There was an important program of scientific papers. Dr. Dixon gave a reception on the second evening and on the third evening there was a banquet in the geological hall of the academy.

The centenary will be marked by the publication of a memorial volume, as well as the issue of a complete index of the academy publications, a work which has been under way for five years. The greatest memorial of the centenary, however, is the completion of the new buildings of the academy, which were temporarily put in shape for the celebration, but in whose new halls the great collections have not yet been fully installed. When finished, Philadelphia will possess in the group of buildings, which will face on one of the most important sections of the great Parkway, a museum of natural history admirably equipped in the way of collections, and in convenience of the exhibtion halls and of the research departments. Everything has been done by the president and the curators, utilizing the money appropriated by the state, to prepare a series of modern halls and rooms beautifully lighted both by day and by night, fireproof and meeting every demand of a modern museum. The result is an imposing group of buildings in brick, terra cotta and granite, with two entrances, one on Race Street, the principal entrance, and the other on Nineteenth Street, which gives access to the main service halls and the fine lecture room and the great library.

The new academy consists of three distinct buildings. The main buildings on Race Street, which replace the old historic centennial building of greenstone, is four stories high and is 184 feet long on Race Street, with a width of 64 feet. The first floor of this main building is given over to a large room with galleries supported by classic pillars, in which will be housed the great Vaux collection of minerals, and other mineralogical and geological treasures. Toward the Twentieth Street end, the valuable herbarium will be housed in the first and second stories, with the working rooms of the botanists arranged with the collections. In the archeological hall Mr. Clarence B. Moore's collection of Indian pottery will be the main feature, together with other collections relating to the history of mankind. Further south along the Nineteenth Street side are the lecture hall on the first floor and above it the great library and reading room. The book stacks are in the rear of the lecture hall, the reading room and the galleries, and run from the bottom to the top of the building. The library and lecture hall are really a separate building, protected by its construction from the menace of fire, its stacks representing the latest improvements and conveniences for the handling of the books.

On the second floor of the main building and the connecting wings there will be found the paleontological hall, 184 feet in length, with a width of 64 feet. This with its double galleries is the largest hall in the building. The connecting wing leading to the Nineteenth Street buildings will be given over to the Pennsylvania and New Jersey local collections, while the

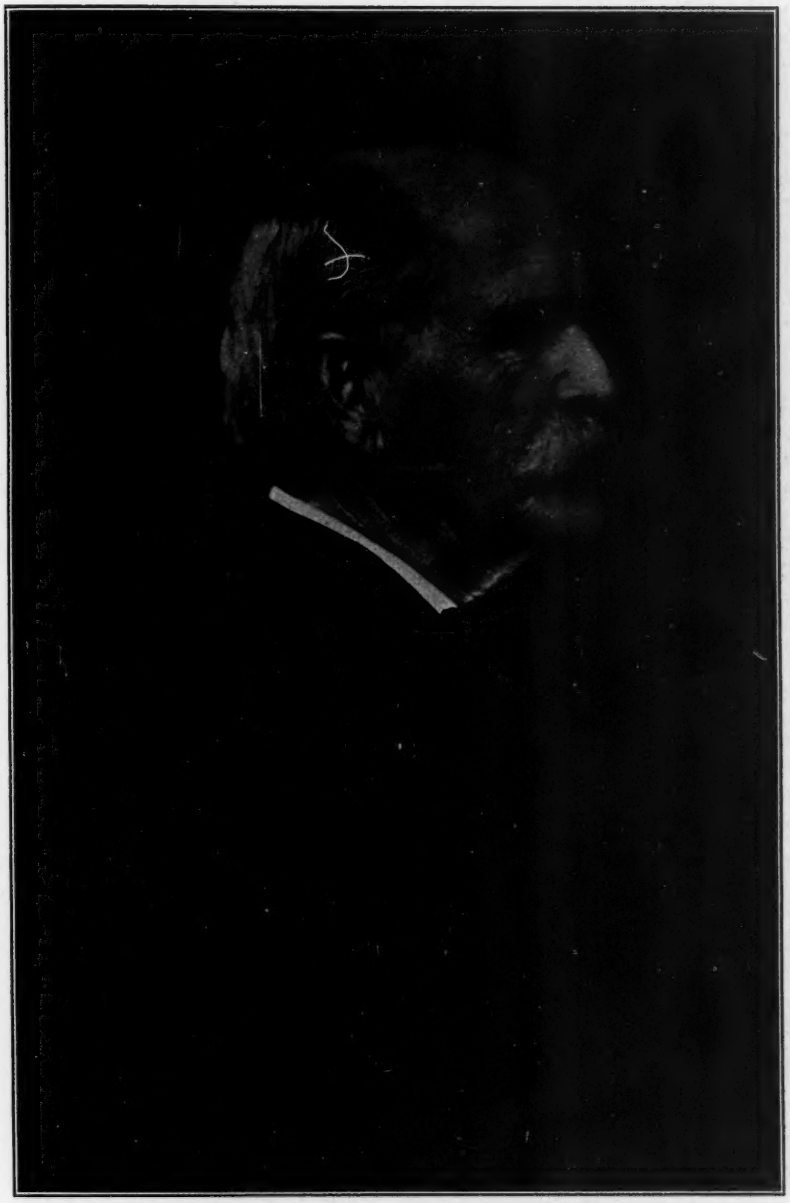
LIBRARY OF THE ACADEMY.

skeletons and mounted specimens of the mammals will be housed in the second story of the first building on Nineteenth Street, the third floor of which is given over to the large collection of birds. In the connecting wing of the third floor will be housed the entomological department, where over a million specimens will be kept in fireproof metal cases, free from dust and moth. The fourth floor of the Race Street building will house the fine exhibition of shells, while the rest of the fourth floor of the buildings will be given over to the very complete working rooms of the scientific staff.

Within the last twenty years, under the presidency of Dr. S. G. Dixon, from an institution largely supported by voluntary membership, the academy has become an endowed institution with an annual income which maintains its work. No state aid has been granted to the academy for maintenance, but in view of the fact that it is the repository of the state geological collections, of very great value, within the last few years generous appropriations have been made for rebuilding, the space in the new buildings of the academy more than quadrupling the space in the old greenstone building in which so much work was accomplished for the advancement of science.

DEATHS AMONG AMERICAN MEN OF SCIENCE

THE hands of death have fallen heavily on our scientific men during the past month. When, earlier in the year Professor Brush died, we realized that, however great the grief may be, it is the way of nature for one who has passed his eightieth year and completed his life's work. Rear Admiral Melville, too, died full of years and honor. But the other deaths have been of men in mid-career, who go leaving unfinished the tasks which they only could do. These are Professors Rotch and Sanger, of Harvard University; Professors Montgomery and Spangler, of the University of Pennsylvania; Professor Smith, of Rutgers College, and Professor Tarr, of Cornell University. The oldest of them was but fifty-four,



GEORGE JARVIS BRUSH.

Formerly professor of mineralogy in Yale University and director of the Sheffield Scientific School.

the youngest thirty-nine. The scientific man, like others engaged in creative work, is likely to have his ideas early, but unlike the man of letters or the artist, he needs a full life to work them out. Science is long and slow, and becomes so increasingly with the accumulated heritage of knowledge.

Abbot Lawrence Rotch, dead after an operation for appendicitis at the age of fifty, was one of the few men of independent means in this country who have devoted themselves to science from love of the work. In 1906 he was given a partly honorary professorship at Harvard University, but twenty years before he had founded and had since directed the Blue Hill Meteorological Observatory, from which have come important explorations of the upper air by kites and balloons. Charles Robert Sanger, born in 1860, was director of the chemical laboratory of Harvard College. In spite of the onerous executive and teaching duties of the office, he found time to carry on accurate researches on the detection of minute quantities of arsenic, antimony and fluorine and on the chlorine derivatives of silicon and sulphur.

Thomas Harrison Montgomery, who died from pneumonia, barely thirty-nine years old, was in charge of zoology at the University of Pennsylvania, where there had just been completed under his direction a laboratory of zoology unsurpassed in the world. His researches on cellular structure and its relation to the phenomena of heredity and the determination of sex; on the activities, habits and development of spiders and birds; on the structure and development of various rotifers and insects and on the analysis of racial descent and of evolution, have been described in more than eighty monographs. Henry Wilson Spangler, like Montgomery, in charge of an important department of the University of Pennsylvania and of a large laboratory of mechanical engineering recently erected, died at the age of fifty-four. He was at the same time a distinguished engineer and a great teacher.

John Bernhardt Smith, born in 1858, was entomologist of New Jersey and of the Experiment Station as well as professor in Rutgers College. He had done important systematic work, but is best known for his economic work, especially on the suppression of the mosquito. Ralph Stockman Tarr, forty-eight years old at the time of his death, was professor of physical geography at Cornell University. He was distinguished for his work in physiography and glacial geography.

SCIENTIFIC ITEMS

LORD LISTER bequeathed nearly the whole of his fortune to scientific institutions and hospitals, including $100,000 to the Lister Institute of Preventive Medicine and $50,000 to the Royal Society.—Professor A. Lawrence Rotch has by his will given the Blue Hill Meteorological Observatory with an endowment of $50,000 to Harvard University.

DR. IRA REMSEN has resigned the presidency of the Johns Hopkins University. It is understood, however, that he will retain the chair of chemistry which he has held since the opening of the institution in 1876.—Dr. George T. Moore has been elected director of the Missouri Botanical Garden to fill the vacancy caused by the resignation of Dr. William Trelease.

SIR J. J. THOMSON has been appointed by King George V. a member of the order of merit. The other scientific men who are members of the order are Lord Rayleigh, Dr. A. R. Wallace and Sir William Crooks. The order has recently lost through death Sir Joseph Dalton Hooker and Lord Lister.—The second annual award of the Willard Gibbs Medal, founded by Mr. William A. Converse, will be made by the Chicago Section of the American Chemical Society on May 17, to Professor Theodore W. Richards, of Harvard University. It may be remembered that the initial award of this medal was made last May to Professor Svante Arrhenius.